Astronomy and Astro-Physics.

VOL. XII, No. 8. OCTOBER, 1893. WHOLE No. 118

General Astronomy.

GREAT TELESCOPES OF THE FUTURE.*

ALVAN G. CLARK.

I have been asked by the local committee, through their secretary, to prepare a paper for the Astronomical Congress, embodying my ideas on the future possibilities in the construction of great telescopes. I accepted the invitation somewhat reluctantly, for, while I appreciate the honor extended to me, I feel that the subject chosen by the committee is a somewhat delicate one to deal with, as I may say many things which do not coincide with the pre-conceived ideas of some that may be present. I beg therefore that they will regard the subject of this paper as simply the embodiment of my ideas. I shall endeavor not to state anything as a fact that has not been demonstrated as such by repeated experiments.

Much has been written and more said regarding the great telescopes of the future. It seems to me that the best method of studying the subject is by a careful consideration of what has been accomplished with the instruments already made. From my personal comparions I find that most of the important original discoveries in the truly visual line have been made with the largest telescopes in use at the time. In making this statement I would say that I do not include such discoveries as have been made from observed irregular proper motions of stars, such as, for instance, the companion to Sirius, which was known to exist some years before it was seen, although this required the largest refracting telescope then in existence to show it to the human eye. When once seen, however, with the large glass, it was readily seen with small ones. Nor would I ignore the many double stars discovered with smaller telescopes. These discoveries have been made with instruments of superior defining power, under fine atmospheric conditions, and are valuable con-

* Read at the Congress of Astronomy and Astro-Physics, Chicago, August, 1893.

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tributions to astronomy, yet I do not believe that a small telescope was *necessary* to make these discoveries. I am of the opinion, that had the discoverers had at their command the largest telescope, the discoveries would have been more numerous and important. When the two 15-inch telescopes were made in 1846, one for Pulkova, the other for the Harvard Observatory, they were considered monsters. I believe it was thought by most astronomers that the limit in size had been reached. No larger refracting telescope was made for a period of more than fifteen years, the next largest being an 18½-inch. I mention this fact to show how and at what time the demand for larger telescopes came. I think that the order for the 18½-inch was given in 1860. As soon as the companion to Sirius was discovered with this glass, at once there seemed to be a desire for something larger. The next larger telescope was made for R. S. Newhall of Gateshead, England. Then came the 26-inch for the U. S. Naval Observatory, and then Leander J. McCormick presented the University of Virginia with one of the same size. After that the 30-inch for the Russian Observatory was constructed, and, finally, the 36-inch for the Lick Observatory. Besides, there is now in process of construction, and well under way, a 40-inch telescope for the University of Chicago.

I have always been a believer in large telescopes for special work. I have had great experience with them, and it is from testing these instruments that I have been convinced that large instruments are needed to make original discoveries, such as new satellites to planets, and faint companions to bright stars, in fact to any stars, as well as for studying the planets and nebulæ. For astro-physical work they are vastly superior to smaller ones. The trouble that early opticians experienced in procuring good discs of glass seems to have passed away, and we are now able to procure discs of almost any size, the only obstacle being the time required to make them, and the money to pay for them.

Having given you some of my reasons for believing in large telescopes, I will now proceed with the subject of this paper, viz.: my ideas of the future possibilities in the construction of great telescopes. It is my idea that the great telescopes of the future will be refractors, not reflectors, and I shall confine myself entirely to the refractor. I would not wish to say anything that might lead you to suppose that I underestimate the value of the great discoveries made with reflecting telescopes, or the great minds that have made and worked with them, yet one person of eminence did remark that *large* reflecting telescopes have never

accomplished much except in the hands of the opticians who made them; and my own experience has been sufficient to convince me that the reflector is extremely sensitive to any changes either of temperature, or air currents, or more particularly to flexure, and that while the refractor is also affected by these changes, it is by no means so injurious to the definition.

As I have said, I believe that good discs of any size, both crown and flint, may now be procured. Having once procured them, all that is required is an optician to work them. He must be an artist in light and shade, and in color also, for the very best correction of the chromatic aberration. As in the light and shade we search for and locate the spherical aberration, so we work among the different colors for the chromatic corrections. It is a very difficult task, and as the size is constantly being increased, the difficulties also increase. Personally I do not believe this work can ever be accomplished by machinery. Not that machinery might not be made available for the rough work and the first polishing, for we ourselves polish all our large surfaces in a machine in a preliminary way. The fine grinding and smoothing, however, is always done by hand. It is after the first machine-polishing is done, and the glass appears to be finished, that what I have referred to as artistic work begins; that is, the work to locate the errors from observations, and correct the surfaces of the glass by the tentative method till all the light from a point at an infinite distance will be refracted to a point at the focus of the objective so accurately that the image there formed will bear the highest magnifying powers without showing any distortion. I believe that this can be accomplished only by most careful study of the light that has passed through the objective, and that all the errors must be worked out by what is termed local corrections.

When the time is ready, I think the man capable of making the necessary observations and locating the errors with precision, as well as skillful enough to work them out on much larger objectives than have yet been attempted, will be found. The simple preliminary grinding and polishing of large lenses is not a very difficult operation; this, with the centering is purely mechanical. But if the glass itself has the slightest uneveness in its density, be it ever so small, the refraction will be different through the different densities. This cannot be determined with certainty until the discs have been worked into an object-glass, or at least, ground and polished for that purpose. If, after this grinding and polishing has been done with the greatest eare, we find the image pro-

duced by the lens which is achromatic is not symmetrical, and that a star at the focus is not round, but possibly is elliptical, rectangular, or in fact of any shape, what is to be done? After so much expense and labor, shall we condemn the glass, and wait perhaps years for other discs, which, after going through the same process, may give no better result? I will state here that of all the large glasses, that is to say over 18½ inches aperture, that have been made by Alvan Clark & Sons, only one, viz.: the Princeton 23-inch, came from the polishing machine giving a perfectly round image. All the others we had to round by local work.

I believe the optician that is to make the large telescopes of the future, as well as the present, must be able to do this work. In my opinion it is not more difficult than the correction of the spherical aberration proper, though if much out, it may prove more laborious. Surely I believe this work should be done rather than condemn the discs and try others. Each glass can be rounded separately. For this purpose set the combined lens in front of a collimating mirror. An artificial star is produced from a lamp by reflecting the light from a minute lens within the eye-tube, and close to the optical axis and focus of the objective. The light from this artificial star passes through the tube to and through the object-glass, then on to the collimating mirror which should be as flat as possible. From the mirror the light returns to all portions of the objective in parallel rays. There must, however, be a little off-set so that the returning light from the star will not fall on the minute lens where the star was first formed, but the deviation from the true optical axis is but a mere trifle. Of course it would be almost impossible to secure perfect definition under these circumstances with a very large glass, as the combined errors or imperfections are made to appear twice as great as they really are, from the fact that the light has passed both ways through the objective, so that the imperfections in the material, that is the glass itself, and workmanship also, are made to appear double what they will be when used as a telescope for viewing celestial objects direct. Nor is this all, for we have the imperfections of the mirror to contend with, and who can conceive of a mirror of five or six feet in diameter resting on its edge, being perfectly symmetrical. You may think it strange if I say that while I should much prefer to have everything perfectly correct for this work, I believe it impossible, and we must do the best we can under the existing circumstances. I remember a time when a distinguished professor was shown by my father,

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our apparatus and methods of testing lenses. The professor asked, which are you testing, the mirror or the objective? My father's reply was, we are testing both, and surely we can test both by the method used.

After observing all the appearances in one position, the next thing to be done is to give the whole or combined glass, that is the crown and flint together, a partial turn. If appearances are changed, it is certain there is some error in the objective, for if the glass worked perfectly, no matter what imperfections were in the mirror, they would be the same which ever way you turn the objective. Having ascertained that the combined glass is not round, or rather does not give a round image of a star a little out of focus, the next thing is to locate the error or errors. Are they in the crown or flint lens? Probably in both. This is, however, ascertained by first revolving one glass. If an irregularity is detected that rotates with the glass, it must be corrected by skillfully working the surfaces, so that the portions that are of short focus shall be lengthened and those of long focus shortened until the rays shall come together at the general focus. After having rounded this lens so that no apparent change is visible by rotation, this glass must remain fixed, and the other must be examined and worked in the same manner. This work having been carefully carried out on both crown and flint lens, they are surely round, though they may not give a round image from the mirror. After the glass is rounded, the mirror itself may be corrected in the same way, but this is not absolutely necessary as we already know the errors. This rounding of a large glass is very laborious, and sometimes requires months to accomplish. Yet the party that is to make great telescopes in the future, as well as the present, should in my opinion make himself familiar with all these tests, and have the ability to work out the errors that I have described, together with those that may arise from concentric rings of different foci.

Having stated my ideas as to the necessary requirements to make large telescopes, I will now call your attention to my idea of the great telescope itself. As before stated I am of the opinion that it will be a refractor, and that its size will progressively increase. It will be mounted equatorially, and provided with the best driving clock that can be devised. I am in favor of the long polar axis, known as the English plan, for such an instrument, my reasons being, first, that a large driving wheel may be applied without setting the telescope to one side of the axis. The polar axis itself may also be braced in any or all directions, without

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interfering with, or obstructing anything. This axis can be made exceedingly stiff by bracing, and the tube itself can be braced to the axis in any position. Such mounting could be easily provided with all the clamps and slow motions that are needed. To make it all complete, we should have two telescopes, one for visual and the other for photographic work, so hung on trunnions as to counterpoise one another, thus requiring very little or no extra weight. I think an instrument mounted in this way would be much more stable than the style Americans have generally adopted in the case of great telescopes.

Now that I have spoken so favorably of these instruments, I must say in conclusion that very much will depend on the localities in which they are placed. To insure the best results, the best places should be selected as the result of thorough preliminary examinations. Doubtless there are many places, both at ordinary and high altitudes, of fine atmospheric conditions. A great telescope, even when used under ordinary circumstances, must be productive of great results, but under the very best conditions of still greater. The increase in size of even our present great refractors, is not a possibility but a fact, and with this will come large acquisitions to our present stock of knowledge. The new astronomy, as well as the old, demands more power. Problems wait for their solution, and theories to be substantiated or disproved. The horizon of science has been greatly broadened within the last few years, but out upon the borderland I see the glimmer of new lights which wait for their interpretation, and the great telescopes of the future must be their interpreters

THE ORBIT OF 37 PEGASI.*

S. W. BURNHAM.

This pair (Σ 2912) has long been recognized as a binary system, but until recently no orbit has been attempted. For the half century following the first measures by Struve, the change in the components was substantially all in the distance which has been steadily diminishing during the whole time. For many years past it has been a very difficult pair, and has often been noted as single. An inspection of the measures shows that until recently the two stars must have been separated by what would be a measurable distance in the largest refractors, though in

* Communicated by the author.

some of the smaller instruments the elongation would be difficult to detect.

The last measure of this pair was made by me at Mt. Hamilton in 1890, with the 36-inch refractor. The distance at that time certainly did not exceed 0″.1. After these measures were made, Mr. Gore computed the orbit (A. N. 3129) and found a period of 117.54 years. As all the measures between 1831 and 1890, had put the smaller star in the second quadrant, this orbit necessarily depended upon my position in 1890, where the companion was placed in the fourth quadrant. I examined this pair on one night in 1889, with the 36-inch, and noted it as single. In the following year I observed it on two nights, and obtained fairly good measures of the angle, the distance being estimated at 0″.1 or less. It was obvious that if an occultation had taken place, the companion could no longer be in the second quadrant, and therefore the angle was given in my observations as 347°.0. A difference in the components of a little more than one magnitude would not be apparent in so close a pair. In the following year (1891) I expected the distance would be increased so that it could be measured without difficulty, but when it was examined under very favorable circumstances with the 36-inch, I found that it was practically single (A. N. 3114). There was no certain elongation on three first-class nights. It follows, therefore, that the position angle in 1890, should have been 167°.0, and not 347°.0 as I have given it in my measures (A. N. 3048). Mr. Gore was doubtless misled by my observations in 1889 and 1890, and assumed, as I did, that the companion had passed around to the opposite quadrant, giving a total angular motion of at least 230° in the sixty years covered by the measures. This would have been sufficient for the determination of a good approximate orbit. It is very probable that my failure in 1889, when the distance could not have been much more than 0″.1, to notice any elongation, and hence calling it single, was a mistake, since it was very carefully observed in 1891; and therefore until the companion reappears no investigation of the relative motion can be made. It is impossible to predict the time when this will probably occur, or whether it will be in the third, fourth or first quadrant. Down to this time the motion is practically rectilinear, and the apparent ellipse, so far as appears, may be either exceedingly eccentric, or the projection of a circular orbit, lying nearly in the line of sight.

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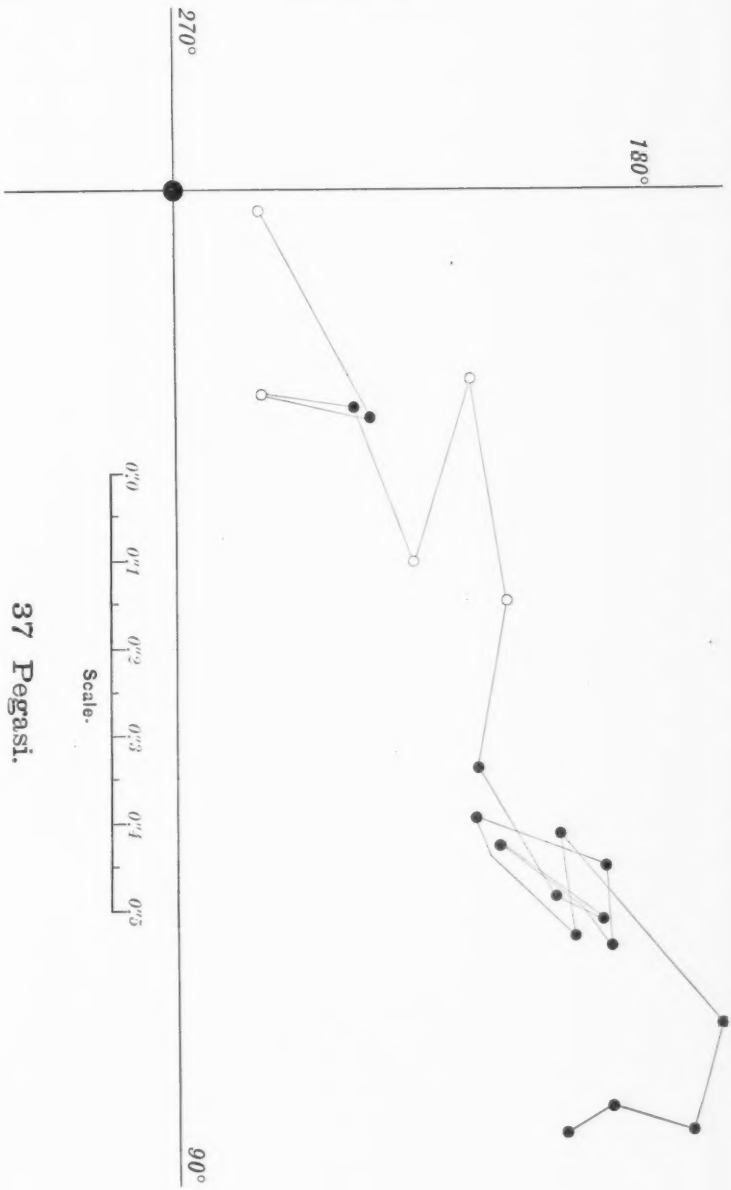
The following are the observations of this pair:

1830-31	132°.2?	1″±	1n	J. Herschel
31.12*	112 6.	1.16	3n	Struve
35.67*	115 .6	1.15	2n	Struve
39.69	119 .0	1.22	1n	Dawes
41.64	106 .2	0.65	2n	Madler
.65*	123 .5	1.13	1n	O. Struve
.88	118 .1	.....	2n	Dawes
42.80*	121 .1	0.85	3n	Madler
43.65*	120 .1	0.82	2n	Madler
.85*	116 .7	1.11	2n	Dawes
45.51*	115 .8	0.79	1n	Madler
47.57*	121 .8	0.97	1n	Mitchell
.98*	123 .9	0.85	1n	Madler
51.85*	126 .2	0.67	2-1n	Madler
.89*	114 .4	1.31	1n	W. Struve
52.67*	116 .4	0.83	1n	O. Struve
53.88*	118 .7	1.11	1n	Dawes
.94*	122 .8	0.81	1n	Madler
54.74*	118 .5	0.91	3n	Dawes
.78	114 .2	.....	1n	Madler
55.82	118 .4	.....	1n	Madler
56.78	127 .7	0.6±	1n	Madler
57.09*	117 .9	0.74	4n	Secchi
.87	116 .3	0.7±	2n	Jacob
58.00	128 .2	.....	2n	Madler
59.87*	129 .3	0.6±	1n	Madler
60.69	119 .8	.....	1n	Dawes
1861.98*	148 .0	0.4±	2n	Madler
63.66	113 .2	.....	3n	Dembowski
66.71	99 .1	0.5±	2n	Winlock
.67	96 .6	0.5±	1n	Searle
.69	132 .9	.....	1n	Searle
.76	116 .4	.....	1n	Searle
67.65	111 .8	oval	1n	Dembowski
68.76	138	.....	1n	C. S. Pierce
69.67	132 .0	.....	1n	C. S. Pierce
.75	114 .8	.....	1n	C. S. Pierce
71.92	122 .3	0.5±	1n	Wilson & S.
72.56	116 .7	obl.	1n	Dembowski
73.78*	119 .3	0.5±	1n	Wilson & S.
.87*	119 .6	0.5±	1n	Gledhill
.88*	130 .6	oval	1n	Dembowski
75.77	.....	invisible	...	Doberck
77.75	118 .8	0.3?	1n	Dembowski
78.63*	130 .0	0.32	1n	Burnham
79.57*	113 .4	0.25±	1n	Burnham
.86	128 .3	.....	1n	Seabroke
80.59	.....	single	1n	Burnham
85.53*	131 .4	0.34	5n	Engelmann
.72	.....	single	2n	Perrotin
89.59	.....	single ?	1n	Burnham
90.56*	167 .0	0.1±	2n	Burnham
91.64	.....	single	3n	Burnham

Leavenworth has a measure made in 1886 (*Publications of the McCormick Observatory*, Vol. I, Part 4) which is credited to this pair, but it obviously belongs to β 291, a close pair in the immediate vicinity of 37 Pegasi.

The relative change in the components will be seen from the accompanying diagram on which the the principal measures are

PLATE XXXVI.



37 Pegasi.

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laid down to scale. These measures are marked with a (*) in the preceeding list. When two or more observations, made in the same year, are used, a simple mean is taken.

The tendency of the observed positions to arrange themselves in groups, which, as I have heretofore shown, is always found in stars of this class where the relative motion is small compared with the errors of observation, is well marked in this instance.

THE DOUBLE STAR, 95 CETI (A. C. 2).*

S. W. BURNHAM.

This star was discovered to be double by the great optician, Alvan Clark, on December 20, 1853, with one of his own objectives of 7½-inches aperture. He sent this, with other newly discovered stars, to Dawes, and in the following year that observer measured the position-angle on three nights. He found it very difficult to measure, and estimated the distance from 0″.7 to 0″.8, the small star being rated as tenth magnitude. Unfortunately, from this time on Dawes paid no further attention to it, and it was wholly neglected or forgotten for nearly a quarter of a century by all other observers. I do not know of a single reference to this pair from the time of Dawes' observations in 1854, until the publication in 1882 of my measures with the Dearborn telescope made in 1878. In this interval, however, it seems to have been looked for at the Harvard College Observatory as appears from some double star observations published about ten years ago. These will be referred to hereafter.

The following are the observations of this pair negative and otherwise:

1854.81	73°.1	0″.7 ±	3n	Dawes
1878.85	.....	Single 18½-in.	2n	Burnham
1886.74	.....	Single 26-in.	2n	Leavenworth
1888.77	112°.8	0.45	2n	Burnham
1890.87	.....	Single 36-in.	2n	Burnham
1891.73	.....	Single 36 in.	1n	Burnham

I had examined this pair many times prior to 1878, commencing with the 6-inch refractor about 1870. In fact, I must have looked at it altogether hundreds of times with various instruments, but until 1888, never could see the least trace of the companion. It began to seem probable that there was some mistake in the identity of the star, or otherwise, as it appeared

* Communicated by the author.

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improbable that the companion in a star of this class, should so long remain invisible. When it was examined at Mt. Hamilton in 1888 with the 12-inch refractor, it was seen and measured with that instrument, the companion being called eighth magnitude. The second measure was made with the 36-inch, and the companion rated ninth magnitude. In 1889, in consequence of my absence on the eclipse expedition, I failed to observe it. In 1890, it was carefully examined on two good nights with the 36-inch, but the companion was invisible. In 1891, on a remarkably fine night, the same instrument with powers up to 1900 failed to show any trace of the companion or elongation of the principal star.

The observations at the Harvard College Observatory, previously referred to, are as follows:

1866.88	12°.9	—	1n	Searle
.88	350 .9	—	1n	Winlock
66.90	26 .7	—	1n	Winlock
67.09	82 .6	—	1n	Winlock

Evidently in at least three of these observations, the companion was not seen at all, and there is nothing to do but reject them all. It will be seen that Winlock's angles differ from each other by more than 90°, and Searle's position does not correspond with either of the others. It is incredible that these observers should have allowed the matter to rest here, without taking the trouble to ascertain which one of the four measures, if either, was entitled to any credit. In the last observation, the seeing was described as "magnificent," but the discordant measures were allowed to stand, and no verification attempted subsequently, and as the first two have nothing to indicate that they were not made under proper atmospheric conditions, there is no justification for selecting any one of these observations, and throwing the other three away.

It is certain that we have in 95 Ceti, a most remarkable binary system. The principal star has a proper motion of 0″.242 in the direction of 104°.8. It is impossible from the two measures we have to say anything about the relative motion. It may be very rapid. The observations of 1888 and 1890 would appear to indicate this. It is possible that the companion has made two or more revolutions since its discovery. At the same time, the failures to see the companion during the fifteen years preceding 1888, rather point to slow change. These doubts will be settled by keeping watch of this star each year, and getting a measure as soon as the companion is again visible. This may be seen any year, and it is important that it should be carefully looked for.

In this connection it may be mentioned that while examining this star in 1890 with the 36-inch, I found a new pair in the field which may prove to be an interesting system. This is a 9m star 31°.7 following, and 5′ 42″ south of 95 Ceti. The components are equal, the distance being about 0″.4 (β 1177).

CHICAGO, Aug. 8.

A FIELD FOR WOMAN'S WORK IN ASTRONOMY.*

MRS. M. FLEMING.

In the earliest records of ancient Greek History we can trace the great interest which centres in the heavenly bodies, and in Astronomy, the greatest of all sciences, but in no way do we find women connected with the study of this science until a comparatively recent date. Caroline Herschel, Mary Somerville and Maria Mitchell were, as women, pioneers in this work. We cannot say these were the only women of their time capable of devoting themselves successfully to this work and of adding to our knowledge of the heavenly bodies and of the laws which govern them. Caroline Herschel and Maria Mitchell had rare opportunities afforded them, the former in that she had a brother who was thoroughly devoted to the work. Probably through him her interest was aroused and she became his assistant and his untiring companion in his researches. Maria Mitchell, in all likelihood, acquired a similar interest in Astronomy from her father, and her high standing as an astronomer is acknowledged by all connected with the study of this science. A great many women of to-day must have a similar aptitude and taste for Astronomy and if granted similar opportunities would undoubtedly devote themselves to the work with the same untiring zeal, and thus greatly increase our knowledge of the constitution and distribution of the stars.

The United States of America is a large country, with a large-hearted and liberal-minded people. Here they have made room for comers from all other countries, have welcomed them and have given them a fair open field and equal advantages in pursuing their labors or studies, as the case may be. There is no other country in the world in which women, not as individuals, but as a class, have advanced so rapidly as in America, and there is no

* Read at the Congress of Astronomy and Astro-Physics, Chicago, August, 1893.

other country in which they enjoy the same unlimited freedom of action which affords them the opportunity to find their own level. In their studies they encounter very little narrow-mindedness or jealousy in their brother students or fellow workers in the same field of research, but in general they are treated with the greatest courtesy, encouragement and assistance being graciously accorded. Women, therefore, who have taken up any branch of science, or indeed work of any kind, need not be discouraged in it even if one or two of the great mass which goes to make up the whole in their superior judgment refuse to give credit to their work. Labor honestly, conscientiously and steadily, and recognition and success must crown your efforts in the end.

Photography, as applied to Astronomy is one of the greatest advances which has been made in this the oldest of sciences, and this same advance has opened up a comparatively extensive field for woman's work in this department. Dr. Henry Draper of New York was the first scientist who photographed successfully the lines in a stellar spectrum. His wife, Mrs. Anna Palmer Draper, was his constant companion and assistant in all his experiments and researches. On the interruption of his valuable investigations by his sudden death in 1882, Mrs. Draper, knowing the great value of the work already done, decided that the investigations should be continued at the Harvard College Observatory under the direction of Professor Edward C. Pickering, and she set aside a liberal sum of money to be used for this work, thus founding the department known as "The Henry Draper Memorial." In 1886 there were three women computers engaged in the work in this department; at the present day there are twelve women engaged in the same or in similar work. Miss Catherine W. Bruce of New York has shown her appreciation of the photographic work now being carried on at the Harvard College Observatory by her generous gift to that institution of $50,000 for the erection of a photographic telescope of the largest size. The Observatoy has a corps of about forty assistants, seventeen of whom are women, and twelve, as stated above, are engaged, more or less, on the photographic work.

The photographs obtained with the various telescopes now in use at the Harvard College Observatory in Cambridge, and at the auxiliary station near Arequipa, Peru, are of various classes, the most important of these being chart plates having exposures of from ten to sixty minutes or more, spectrum plates having exposures of from ten to sixty minutes, and trail plates having sev-

eral exposures of a few seconds duration. The women assistants are not engaged during the night in taking these photographs but find their time during the day sufficiently occupied in examining, measuring, and discussing them, and in the varions computations therein involved. Catalogues, for reference, of the plates taken with each instrument have to be kept up to date, the plates have to be compared with the charts of the part of the sky which they are supposed to represent, in order to check the correctness of the record made by the observer, and to ascertain that the region intended is contained on the plate. The chart plates are then filed carefully away and are used in the confirmation of variable stars or other interesting researches. The most important work at present being done from the chart plates taken with the 8-inch Draper telescope in Cambridge, and with the 8-inch Bache telescope in Peru, is the measurement of the faint stars for stand ards of stellar magnitudes. These measurements of about forty thousand stars are now being made by Miss Eva F. Leland. She is also engaged in the measurements of the brightness of the stars in clusters. Miss Louisa D. Wells and Miss Mabel C. Stevens have shown great skill and accuracy in making the identification of stars shown in the photographs, with those contained in existing catalogues. The photographs of stellar spectra are all carefully examined in order to detect new objects of interest, such as third type stars, fourth type stars, fifth type stars or those, whose spectra consist mainly of bright lines, and similar to those discovered in Cygnus by Wolf and Rayet, planetary nebulæ, and variable stars. All of these except the first named class differ so much from the general mass of stellar spectra, that a trained eye has little difficulty in detecting them on the photographic plates, even although the objects found are sometimes as faint as the ninth magnitude. If an object is detected on any of the photographs showing a spectrum of the third type, having also the hydrogen lines bright, it is at once suspected of variability, since only variables of long period are known to possess this peculiarity. The catalogues of the plates taken with the different instruments are then consulted, and a list is made of all the plates covering the region of the star suspected of variability. So you have, ready to your hand and for immediate use, the material for which a visual observer might have to wait for years and certainly for months. This material must also be considered more reliable, for in the case of a visual observer, you have simply his statement of how the object appeared at a given time as seen by him alone, while here you have a photograph in which every star

speaks for itself, and which can at any time, now or in the years to come, be compared with any other photograghs of the same part of the sky.

Many interesting discoveries have been made from the study of these photographs of stellar spectra. First in importance among them, was the discovery that ζ Ursæ Majoris is a close binary star, the two components revolving around each other at a velocity of about a hundred miles a second, in a period of about fifty-two days. This discovery was made by Professor Edward C. Pickering, his attention being first attracted to it by the fact that in the photographs of the spectrum of this star, the lines appear sometimes double and at other times single. This discovery led to the finding of a second object of this same class, β Aurigæ, by Miss Antonia C. Maury. This last star has attracted public attention much more widely than ζ Ursæ Majoris and may be considered more interesting in that the period of revolution of the two components is only 3 days 23 hours and 36.7 minutes. ζ Ursæ Majoris and β Aurigæ are such close double stars that they could not possibly be separated visually with the most powerful instruments at present in use. A third object of this class is suspected in β Lyræ which shows a similar change, or rather it shows a reversal in the position of the bright lines with regard to the dark lines in its photographic spectrum, that is, they apparently cross and re-cross each other. This is doubtless associated with the variation in the light of this star since the period is the same for both. The examination of the photographs of the brighter stars has been made by Miss Maury who has also been engaged on their classification. The micrometric measurements of the lines in the photographic spectra of the bright stars have been made by Miss Florence Cushman.

From the examination of the photographs of stellar spectra, thirty-eight stars having spectra of the fifth type have been added to the sixteen previously known, making the known number in all fifty-four. Three of the stars in this list have been discovered during the past few days and have not as yet been announced elsewhere. Twenty-three new variable stars have been discovered in this same examination of the photographs, and before being published each and all were confirmed by Professor Pickering. Two of the twenty-three have not yet been announced elsewhere since one of them was discovered only yesterday. This star is in the wonderful southern cluster ω Centauri, the finest in the sky, and being so situated would probably never have been discovered by other means than photography.

The other star is in Columba and is the first variable discovered in that constellation. Its position for 1875 is in R. A. $5^h\ 45^m\ 41^s.9$, Dec. $-29°\ 13'.7$.

One must not always cling to the earliest method of accomplishing anything and assume that because it was the earliest and has held sway for centuries, it must consequently be the best, and also the only way. Where should we be to-day if we did not advance steadily in all things? Taking light for instance, first we have rude torches and rush lights, then candles by which the day was measured off into hours, this followed by lamp light, later by gas light, till now we have electricity to light our streets and our dwellings. And powerful as electricity is in itself for all purposes to which it has been applied, who among us can say that in it we have attained the highest degree of perfection in illumination? So it is with everything else we may take up, and so it is with astronomy. And thus while the old time astronomer clings tenaciously to his telescope for visual observations, astronomical photography is leaving him far behind and almost out of the field in many investigations which nevertheless he still continues in his own way, trying also to maintain that, as stated above, it must be the best, if not the only way. If photographic work is to be entirely ignored by the astronomers of the old school as they may be called, because, as they themselves say, they have no knowledge of photography, and not having the means at their command, do not wish to acquire a knowledge of it, what is to become of the researches planned and undertaken by the Astro-Photographic Congress of Paris, in which astronomers of all countries have united? We may safely say that the younger, more advance guard of civilization will uphold photography and encourage it as applied to astronomy, as in other scientific researches in which it is also successfully employed.

A new variable star in the constellation Delphinus was discovered from the photographs some time ago, and was announced in "The Sidereal Messenger," Vol. X, p. 106. Two skilled visual observers undertook to observe it in order to confirm, or refute, its variability. One arrived at the conclusion that it was not variable and was always about the ninth magnitude, while the other also found that the star was not variable, but according to his observations it was always about the eleventh magnitude. When they met together to discuss this difference in magnitude, they discovered that each had been observing a different star, and further, that neither of them had observed the variable. No such error could have occurred from the comparison of the photographic charts.

Unlike telescopic observations, the photographs are available always, at any time during the day or night, for consultation and examination. Therefore, while an observer with a telescope, be it even the most powerful that can be made, is at the mercy and dependent upon the state of the weather for his observations, the discussion of the photographs goes on uninterrupted and is undoubtedly much more reliable than visual work, since when a question of error in observation arises, anyone interested in the research can, at any time, revise the original observation by another and independent examination of the photograph.

Given the instruments, and materials required, with a knowledge of how the instrument is used, you can obtain in one night what would represent years of hard labor in visual observation, and in the necessary computation involved in reducing and charting these same observations. Even when finished the visual observer's chart may be subject to various errors in the positions or in the brightness of the stars with which he has dealt, but the photograph cannot fail to be an exact and unquestionable record which can be consulted and compared with others years hence, and thus serve to prove or disprove variations in light, changes in position, and in the case of the spectrum plates, changes, if any, in the constitution of the stars. Thus on a photographic plate, on which it has taken only a few minutes to reproduce the portion of the sky covered, you have a true chart of the stars in that part of the sky at that time, the limiting magnitude being dependent on the duration of the exposure and also on the sensitiveness of the plate used.

In a catalogue of variable stars recently published and entitled "Second Catalogue of Variable Stars," a more correct title would be "Second Catalogue of Variable Stars discovered Visually," since in it no weight is given to photographic observations further than is necessary to enable them to swell the list of stars discovered visually. Stars discovered photographically which have been announced as variables, and have been proved beyond doubt to be variables, are here credited as "suspected."

In conclusion, while I may be thought to have strayed far afield from the subject on which I was supposed to address you here, the investigations and researches described above are those in which the women in this department are engaged, in which they are thoroughly interested, and in which they are becoming trained and competent assistants.

While we cannot maintain that in everything woman is man's equal, yet in many things her patience, perseverance and method

make her his superior. Therefore, let us hope that in astronomy, which now affords a large field for woman's work and skill, she may, as has been the case in several other sciences, at least prove herself his equal.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., August 4, 1893.

ω CENTAURI.*

SOLON I. BAILEY.

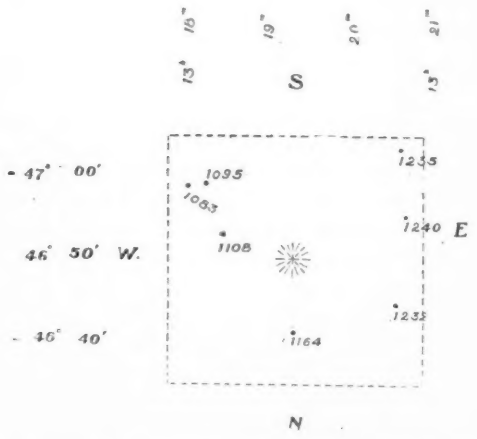
The cluster ω Centauri lies just within the northern border of the Milky Way at R. A. $13^h\ 19^m\ 16^s$; Dec. $-46^\circ\ 49'.5$ (1875, Gould).

All the stars within a radius of 5° are of the sixth magnitude or fainter. To the naked eye the cluster appears as a hazy star of less than the fourth magnitude. In a field-glass, it becomes a globular mass of nebulous light, dense at the centre, and gently fading away at the border. The globular form is in general very perfect, but to the north it appears slightly flattened. With a telescope of high power it becomes a maze of faint stars, well defined and separated, but projected, toward the center of the cluster, upon a background of faint nebulous light. Some interesting photographs of this cluster have been made recently with the Boyden telescope of 13-in. aperture and 16 feet focal length. A brief study has been made of the number and distribution of the stars composing this group as shown on one of these photographs. The plate was made May 19, 1893, and the exposure was two hours. The 8-in. finder, which had been previously used for purposes of following, was found after many trials to be incapable of giving sufficiently exact results for this work, and an eyepiece was inserted into the field of the main telescope itself. By this means the photographic images were greatly improved. The precise limits of the cluster are hard to define, but for the purposes of this study a region 30′ square was taken, having for its centre the centre of the cluster. As may be seen from the diagram giving the enumeration, the cluster fills this region fairly well and perhaps extends a little beyond. Within this region is no star so bright as the eight magnitude. A field-glass of good power shows no individual star. Within this region Dr. Gould in his

* Communicated by Edward C. Pickering Director of the Harvard College Observatory.

"Zones" gives seven stars: 13 h. 1083, 1095, 1108, 1164, 1232, 1235 and 1240. The magnitudes given are respectively 8½, 8½, 9, 8½, 9, 9, 9. The position of these stars in respect to the centre of the clustre is shown in diagram 1. They are found on the photograph in squares Ea, Eb, Id, Pk, Ms, As, and Gs. (Diagram 2). They include all the brighter stars of the cluster. The magnitudes now correspond fairly well with those given above, with the exception of 1095. My estimates of the visual magnitudes are 8.7, 9.5, 8.8, 8.5, 9, 8.8, 9.2. In the zones, 1095 is given equal in brightness to the close star 1083. It is now nearly a magnitude fainter and may be a variable. Photographically, 1108 is about the same brightness as 1164 and 1235 is brighter than 1083.

DIAGRAM 1.



For the purpose of the count, a series of black lines were drawn on white paper, one centimetre apart. Four hundred squares were thus formed. This was then photographically reduced on glass and a glass print made giving a transparent field with fine dark lines. The size of this reticule was 4.4 c. m., and its scale was such that the region covered was 30′ square, each little square having for its side 90″ of arc.

This reticule was placed over the negative, the whole placed in a frame having proper illumination and the number of stars in each square counted. A compound microscope, with a magnify-

ing power of 40 diameters, was used. The cross-hairs of the eyepiece divided each square into four sub-squares, which served to prevent confusion in counting. By estimate the photographic stellar images, except in the case of a few of the brighter stars, differed very little from 4″ in diameter. With the magnifying power used, the images had a slightly elliptical form, which, however, proved an advantage as it enabled the star images to be distinguished from any possible imperfections in the plate.

DIAGRAM 2.

S

	65	78	110	146	201	280	335	470	637	681	672	632	568	476	339	253	185	141	103	83	6389
A	2	2	2	4	3	1	4	4	6	3	2	3	6	3	7	5	6	6	3	3	75
B	2	4	5	3	4	4	4	4	4	3	6	5	6	5	10	6	7	3	4	3	92
C	2	2	4	7	10	8	4	8	4	9	8	10	8	10	7	6	5	10	4	2	128
D	2	0	2	6	5	4	7	6	10	10	12	14	6	12	4	10	6	4	4	8	132
E	4	2	6	6	10	6	9	10	10	18	26	18	11	19	7	7	12	6	4	6	197
F	3	2	5	6	6	14	19	19	22	23	24	26	25	11	12	3	5	5	4	248
G	5	6	8	6	9	12	25	26	34	47	34	44	32	38	16	12	13	8	10	7	392
H	5	6	6	16	10	23	26	30	52	54	58	59	44	46	27	26	14	14	7	4	524
I	6	8	8	10	21	28	37	60	75	81	66	74	62	58	44	20	10	9	4	8	689
J	3	4	7	12	14	31	46	65	89	91	93	92	71	62	42	24	10	6	6	4	777
K	4	6	13	18	21	34	40	62	88	100	96	80	66	54	35	27	10	15	6	6	781
L	2	10	5	9	14	38	33	52	77	74	83	68	48	42	44	27	25	6	8	8	673
M	2	6	5	13	13	26	29	40	62	71	62	58	38	32	24	16	16	14	10	4	538
N	6	3	10	10	18	22	18	28	38	32	29	29	32	20	8	16	10	12	6	1	348
O	3	5	4	4	10	12	12	18	30	28	21	20	18	14	12	12	8	6	4	8	249
P	3	6	4	4	5	4	5	16	10	18	14	10	12	9	12	7	8	4	4	1	156
Q	4	1	8	6	5	4	8	9	12	6	12	10	10	6	12	8	5	5	6	2	140
R	0	2	4	1	8	7	9	8	9	6	10	8	8	8	6	10	4	5	4	2	119
S	4	1	3	3	10	4	2	3	5	6	4	2	2	3	4	0	1	3	2	2	64
T	1	2	1	2	4	1	6	2	3	2	8	4	6	10	4	2	6	0	3	0	67
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	6389

W E

N

All objects not of this form were rejected. Toward the center of the cluster, counting was somewhat difficult but doubtful objects were discarded. The numbers given do not represent the full number of stars that left their impression on the plate. Toward the center of the cluster, the background between the distinct images was of a faintly mottled gray, apparently due to stars too faint and closely packed to make distinct records. No account was made of this background except where it became sufficiently differentiated to assume the peculiar form referred to above.

Near the center of the cluster, chiefly in square Jj, occurs a peculiar break in the brighter stars. The number is preserved, however, since there is a background of fainter stars.

Diagram 2 shows the number of stars counted in each square. The sums at the side and top show in a general way the condensation toward the center. The cluster was counted independently, twice, once by Mrs. Bailey and once by myself. The results obtained were 6402 and 6373 stars respectively. The

disagreement arose from the fainter mottled background, as the negative showed every gradation from a nearly even shading to a decided mottling. This appearance seems to be due to close faint stars rather than to nebulous matter. The numbers given in the squares are the means of the two counts, and the sum of the means, 6389 stars, may be safely assumed to be the approximate number of stars that made distinct impressions on this plate.

There can be no doubt, however, that the whole number of stars comprising this splendid cluster is very much greater.

AREQUIPA, Peru.
June 30, 1893.

POLAR INVERSION OF THE PLANETS AND SATELLITES.*

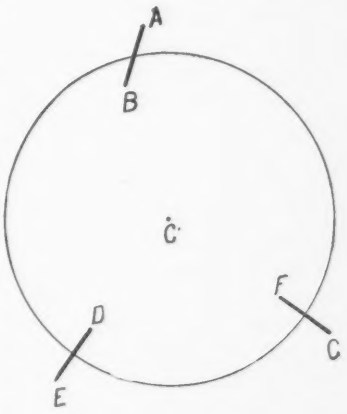
WILLIAM H. PICKERING. †

By the term Polar Inversion is meant the gradual turning over of a planet, so that its north pole occupies the position formerly held by its south and *vice versa*. In ASTRONOMY AND ASTRO-PHYSICS for June the inversion of the poles of the directly rotating planets and satellites of the solar system was ascribed to the action of the tides set up in them by their primaries. This action appears to be sufficient to explain the inversion in the case of the satellites, and in general of any body whose period of rotation upon its axis is not less than its period of revolution around its primary. It does not, however, fully explain the case of rapidly rotating bodies like the planets, since in their case the inversion could not proceed much further than to make the axis coincide with the plane of the orbit. A second cause of inversion has recently been found which in its action is probably still more important than that of the tides.

Let us first imagine a wheel AB, whose axis coincides with the plane of its orbit about its primary C. The part B will be attracted more than the center of gravity of the wheel, and the part A will be attracted less. The tendency will therefore be to cause the wheel to turn so that its plane AB shall pass through C. If the attraction is sufficiently powerful, or is continued indefinitely, this position will be maintained in all parts of its orbit, as shown at DE and FG. If, however, the wheel begins to rotate upon its axis, a new series of forces will come into play. The

* Communicated by the author. † Harvard College Observatory.

effect of the rotation will be to cause the wheel to endeavor to retain its original plane in spite of the attraction of the central body. Nevertheless this attraction will produce a certain effect setting up a very slow rotation of the plane of the wheel about an axis perpendicular to the plane of its orbit. If the plane of the wheel had been inclined to the plane of the orbit, instead of perpendicular to it, the same effect would have been produced, only the rotation of the plane would have been in this case still slower.



Let us now take any rotating body, revolving in a retrograde direction, and change the plane of its rotation by a direct rotation perpendicular or inclined to the primary axial rotation. The result will be that the body, if left free to itself, will slowly invert its poles, and take up a plane of rotation parallel and in the same direction as the disturbing rotation. This action of rotating bodies is a well known principle. For a convenient mathematical demonstration of it see Johnson's Encyclopedia, article Gyroscope, by Professor J. G. Barnard.

We may therefore say that since such a disturbing rotation necessarily occurs in all the planets and satellites of the solar system that the poles of such of them as have like Neptune and Uranus a retrograde rotation, must in process of time be inverted, and that in the end all of them will sooner or later assume planes of rotation parallel with the planes of their orbits.

HARVARD COLLEGE OBSERVATORY,
Sept. 6, 1893.

ON THE FORM OF THE CORONA APRIL 16, 1893.

J. M. SCHAEBERLE.

With reference to the form of the corona April 16, the hasty and unguarded remarks attributed to Messrs. Pickering, Fowler

* Communicated by the author.

and Taylor in the August number of *The Observatory* are not, according to my view, in agreement with the actual facts.

I have not seen the results obtained by other expeditions and can therefore only refer the reader to my own "preliminary note" on this subject printed elsewhere.

A reviewer in the August number of *Ciel et Terre* concludes that—because the polar extent of the corona, as shown on photographs obtained by others, is greater than the equatorial extent—my theory does not hold good, as the predicted form shows the opposite arrangement! While it is quite true that some of the particularly brighter streamers of the *outer corona* give this general impression, still, on my photographs of the outer corona, the equatorial extent—which is lost in ordinary printing, can be traced to a distance of at least eight solar diameters from the sun, while in the polar direction the last trace of coronal light is lost at something less than one-half of this distance. Now from a provisional study of my own photographs of this eclipse I have no hesitation in making the following statement:

The photographs of the corona (central) *taken by every expedition sent out to observe the eclipse of last April will invariably show that the brightness and extent of the inner corona was greatest in the spot-zone regions!*

In this eclipse (as in all the other eclipses of which I have phottographic copies) the significant fact that the polar brightness and extent of the *inner* corona was actually less than the equatorial, gives strong evidence that the apparently conspicuous polar streamers of the *outer* corona do not have their origin in the Sun's polar region, but are only seen in projection, at the poles, at great distances from the origin, and consequently are comparatively faint at the Moon's outline.

It will be conceded by all that from the very nature of my theory only a general and ideally typical form corresponding to a perfectly uniform distribution of the eruptive forces can be considered in making predictions. Any attempts to predict the actual positions which all the eruptions in the spot-zones will have at some future particular instant of time would evidently be mere guess work.

Now granting for the moment that the *Mechanical Theory* is true, it would still be as impossible to predict accurately the exact form of the corona at some future particular instant of time as it would be to predict all the exact meteorological conditions at a given place for the same instant of time.

To guard against any possible misconception as to the nature

of my prediction I specially stated that it was evidently impossible to predict features due to a (most probable) deviation from a symmetrical arrangement of the forces in the spot-zones.

In view of the fact that I had previously a seeming confirmation of my theory, as applied to this eclipse, the criticisms above referred to called for an answer.

For further information the reader is referred to the "preliminary note" already mentioned, and to the full report on this eclipse which is now in preparation.

LICK OBSERVATORY, Sept. 6, 1893.

ENGINEERING PROBLEMS IN THE CONSTRUCTION OF LARGE REFRACTING TELESCOPES*

WORCESTER R. WARNER.

The continued and growing demand of astronomers for larger and more far-reaching telescopes has presented an entirely new series of problems, for the solution of which the best talents o the engineer are brought into play.

Size and penetrating power, while most important, are not the only requisites of the great telescopes of to-day; for they must be specially designed and arranged for spectroscopic and photographic as well as for micrometric and visual work. This combination of uses greatly increases the complexity of the problems and the difficulty of their solution. The suggestion has been made periodically for the last fifty years that the proper system of construction for large telescopes is to place the optical axis of the instrument in a horizontal and permanent position on the ground, pointing due south, and to reflect the images of the heavenly bodies into it by means of mirrors. This would at first sight seem a happy solution of the engineering problems, were it not for the fact that in large instruments it introduces optical difficulties well-nigh insurmountable; for the mirrors must be much larger than the objectives into which they reflect the light, and to give good results their surfaces must be optically perfect, and must be mounted so as to be free from deflection in all positions. These conditions are so difficult to obtain that, for large telescopes, this system is practically ruled out, while for small or medium sized instruments, the ordinary construction with a movable tube is much more convenient.

* Read at the Congress of Astronomy and Astro-Physics, Chicago, 1893. For illustration see Frontispiece.

Professor Langley has, however, recently erected at the Smithsonian Institution a 12-inch horizontal refracting telescope, having an 18-inch plane mirror, which is said to be very perfect and successful in its operation. It is the form known as the Siderostat.

Again, much study has been given to a form of telescope known as the Equatorial Coudé, in which the optical axis of the telescope is parallel to the axis of the Earth, and the light of the star is reflected into it by two mirrors. This is very convenient for the astronomer, who can sit in his chair and observe the stars as easily as he can use his microscope; but the loss of light and definition by the double reflection, as well as the deflection of the mirrors, and the varying temperatures to which the different parts of the instrument are subjected, render this construction far from perfect; so the problems incident to mounting the largest telescopes with movable tubes still confront us.

The three largest telescopes in this country, *viz*;—the new 26-inch equatorial of the Naval Observatory at Washington, the 36-inch Lick telescope at Mt. Hamilton, and the 40-inch Yerkes telescope, just completed for the University of Chicago, and now erected in the Manufactures and Liberal Arts building at the World's Columbian Exposition, may serve to illustrate some of the modern methods of solving these problems, and form the subject of this paper. As the last mentioned and largest is the most available for examination, we will confine the discussion to it.

In designing a large telescope, the first element to which the engineer naturally gives his attention is the tube; for, while its office is a very simple one, being merely to hold the objective and the eye-piece in their proper relation to each other, and to enable the astronomer to direct the optical axis to the star, it is an extremely important factor.

The two most essential points in the tube are lightness and rigidity, the former for ease of motion and the latter to reduce flexure to a minimum. The material best calculated to give these two qualities seems at the present time to be sheet steel. Some material having aluminum as a base has been sought for, but thus far none has been found giving the requisite rigidity.

The form of the tube has much to do with its rigidity, a slight increase in diameter at the center serving to stiffen it to a great degree, and cause thinner material to suffice. No form of internal bracing seems so effective as the same amount of material used in the shell itself. In the tubes of the three large telescopes named there is therefore no bracing whatever, all the strains, both in

tension and compression being taken by the sheet steel forming the tube.

The tube for the 40-inch Yerkes telescope is 42 inches in diameter at the objective end, 52 inches at the center, and 38 inches at the eye end. The sheet steel forming the tube varies from 7.32 inches in thickness at the center to 1.8 inches at the ends. The total weight of the tube is six tons.

The declination axis carrying the tube is of forged steel, 12 inches in diameter and 12 feet long, its weight being 1½ tons. This runs in segmental babbitt bearings in the declination sleeve, which weighs 4 tons. The polar axis carrying the whole system is of hard forged steel, 15 inches in diameter at the upper bearing and 12 inches at the lower bearing, and weighs 3½ tons.

Just above its upper bearing it carries the main driving gear, weighing one ton and having 330 teeth, by which the movement of the driving clock is communicated to the polar axis.

The great weight of the bearings of these axes is almost wholly relieved, and the resistance changed from sliding to rolling friction by means of three bracelets or live rings of steel rolls. One of these encircles the declination axis near the tube, and one is placed above each bearing on the polar axis. These anti-friction live rings run in steel yokes, and are pressed against the axes by means of adjustable spring levers.

The live ring of rolls which is on the declination axis near the tube is the center of gravity of the system comprising the tube and the declination axis with their attachments, this one series of rolls serving to take the weight off both bearings of the declination axis, and so nearly eliminating friction that less than one pound of direct pressure on the tube is required for each ton of weight moved. This live ring is composed of 16-inch rolls, 5 inches long, and 3 inches in diameter, and carries a total weight of eight tons.

The live ring at the upper end of the polar axis is composed of 16 rolls, 6 inches long, and 4 inches in diameter. This sustains a weight of nearly 20 tons. The end-thrust of all this great weight, due to the angle at which the axis is placed, is taken on a double series of 40 one-inch hardened steel balls.

The methods of balancing the movable parts of the Yerkes telescope have been a special study, with results which seem all that can be desired.

The heaviest accessory to be used with the telescope is the solar spectroscope. With this in position, the tube is accurately balanced. Weights are then placed on the extension of the declina-

XUM

tion sleeve until the whole system is in balance. When the solar spectroscope is to be removed sufficient supplementary weights are placed at the side of the eye end of the tube, so the balance is not disturbed.

The equatorial head and its bearings supporting the polar axis and the entire movable part of the telescope, is cast in one piece, its base conforming to the rectangular shape of the column.

The column is 11 ft. × 5 ft. at the base, tapering to 10 ft. × 5 ft. at the head. It is cast in five sections, having internal flanges for securely bolting it together. In the upper section is placed the driving clock. A spiral staircase at the south side of the column gives easy access to the driving clock, and also to the balcony surrounding the head.

The Driving Clock is governed by a double conical pendulum, mounted isochronously, and making sixty revolutions per minute.

A driving weight, considerably in excess of the amount required to drive the telescope, is used with this clock, the surplus of power being taken by a friction ring placed just above the pendulum. The arms of the pendulum are so arranged that in operation they always take their natural and theoretical positions, not being swerved therefrom by the action of the power on the friction ring above mentioned. When the clock is unclamped from the polar axis, all the power required to move the telescope is instantly transferred to the friction ring, and the pendulum maintains its theoretical position and normal rate. An electric motor is provided for automatically winding the clock.

All clamps and slow motions, both in declination and right ascension, are operated by handles at the eye end within easy reach of the observer, while the assistant on the balcony can also set the telescope in any position and read the circles. In addition, electric motors are provided for operating all quick and slow motions, and clamps.

These various motions and clamps being operated by the astronomer at the eye-end of the tube either by hand or by means of the electric motors, and also by the assistant on the balcony, are so arranged that any one method of working them is not interfered with by either of the others. Each motion is therefore always ready for action and no conflict is possible.

Incident to the construction of large telescopes, problems are presented in providing domes to cover them, and elevating floors by means of which their use is made more convenient.

These problems have been very satisfactorily solved, for the domes of the best construction will revolve by a direct power of two pounds per ton of weight moved.

Elevating floors of nearly the diameter of the domes are in successful use with the 36-inch Lick Telescope and also with the 26-inch telescope at the new Naval Observatory at Washington. Both these elevating floors are operated by hydraulic power, the simple movement of a lever sufficing to raise or lower them.

Such is the solution of some of the problems incident to the construction of large telescopes and their equipment to-day. What improvements the morrow may bring forth it were hazardous to predict.

DETERMINATION OF THE LONGITUDE AND LATITUDE OF THE NEW NAVAL OBSERVATORY WITH REFERENCE TO THE POSITION OF THE OLD OBSERVATORY.*

By PROFESSOR J. R. EASTMAN, U. S. N.

The observations for this work were made by Professor J. R. Eastman, U. S. N., and Assistant Astronomer, A. N. Skinner.

The reference point for both longitude and latitude of the *old* Naval Observatory was the center of the old dome on the main building. The latitude of the transit-circle pier was the same as that of the old dome.

At the *new* Observatory the longitude is referred to the meridian passing through the centre of the clock-room, which is midway between the east and west transit-circle observing rooms. The latitude is referred to the line joining the centers of the east and west transit piers. At the intersection of this parallel with the meridian in the clock-room a metal plate, properly marked, will be inserted in the floor, and this is taken as the reference point for the longitude and latitude of the new Observatory.

The Longitude.—The plan for this work contemplated the determination of chronometer corrections at each station, the telegraphic exchange of chronometer signals at about the middle of each night's observations, exchange of stations by the observers, and the determination of the personal error of each observer each night with the personal equation apparatus. Similar instruments were used at both stations, consisting of a portable transit of 2.5 inches aperture, sidereal break-circuit chronometer, chronograph, a key and switch-board for facilitating exchange of signals, and a personal equation apparatus. The transit, chronograph and switch-board were a portion of the outfit for the

* Communicated by F. V. McNair, Superintendent of the Naval Observatory.

transit-of-Venus parties in 1874 and 1882, and require no special description. The personal equation apparatus is described in the Observatory volume for 1875. Observations for longitude were made on eleven nights; Professor Eastman observed six nights at the new Observatory, and Mr. Skinner six nights at the old Observatory. The values of the scale divisions of all the levels were determined before the observing began by means of the level trier belonging to this Observatory. The observations were reduced by the method of least squares, in the usual way to determine the corrections to the assumed chronometer correction and the assumed values of the collimation and azimuth constants, and to obtain the hourly rate of the chronometer.

With the corrected collimation and azimuth constants the computation of the chronometer correction for each star was completed. These corrections for each date were compiled, corrected for rate, and the mean corrections, together with the probable errors, were computed.

The uncorrected results of the exchange of signals were then corrected for the error of chronometer, and the observer's personal equation and the difference of longitude between the two stations, for signals in both directions, was obtained. The mean differences of longitude between the stations for each date are given below, together with the mean of all the dates, computed by using for the weights the squares of the reciprocals of the probable errors.

		s	s
March	9	3.696	± 0.021
"	13	3.630	± 0.028
"	16	3.778	± 0.024
"	28	3.732	± 0.021
"	31	3.677	± 0.025
April	4	3.628	± 0.022
"	5	3.712	± 0.036
"	21	3.624	± 0.021
"	24	3.599	± 0.018
"	27	3.746	± 0.018
"	28	3.632	± 0.018
	Mean	3.6738	± 0.012

The transit at the old Observatory was mounted on the old transit circle pier 76.8 feet = 0ˢ.0656 *west* of the reference meridian. The transit of the new Observatory was mounted on the west transit-circle pier 81.8 feet = 0ˢ.0690 *west* of the reference meridian. Therefore, from this determination, the reference meridian of the *new* Observatory is

$$3^{s}.670 \pm 0^{s}.012$$

west of the meridian of the *old* Observatory.

The Latitude.—The two Transits were used as zenith telescopes to determine the approximate difference of latitude between the *old* and *new* Observatories.

The same observing list of stars was used at both stations, and practically the same stars were used each night, at each station.

The observations at the *old* Observatory were made by Mr. Skinner and those at the *new* Observatory by Professor Eastman.

The values of one revolution of the micrometer screws were determined by Professor Eastman by rotating the micrometer 90° and observing the transits of stars, between 54° and 84° north declination, over the single thread used in the observation, as it was moved forward over uniform spaces until the whole range of the thread, during the observations, was covered.

At the *new* Observatory *nine* stars were observed and the value of one revolution of the screw was found to be 68″.970.

At the *old* Observatory *eleven* stars were observed and the value of one revolution of the screw was found to be 68″.601.

An average of nine pairs of stars were observed each night. The mean result of each night's work at each station is given below, together with the adopted mean of the observed latitudes of each Observatory.

	Old Observatory.		New Observatory.	
May 8	+ 38° 53′	38″.22 ± 0″.23	+ 38° 55′	14″.05 ± 0″.20
9		38 .17 ± 0 .12		14 .15 ± 0 .19
10		38 .25 ± 0 .16		14 .10 ± 0 .10
11				14 .03 ± 0 .16
Mean	+ 38° 53′	38″.20 ± 0″.018	+ 38° 55′	14″.08 ± 0″.015

As these observations were made at both stations with precisely the same apparatus, using the same stars, the probable error of a single night's work at each station was found, by treating the above seven results together, to be 0″.031, with the resulting probable errors of the mean results at each station as given above.

The observed difference of latitude between the two reference points is

$$1' 35''.88 \pm 0''.023.$$

Assuming that the adopted latitude of the *old* Observatory,—+38° 53′ 38″.80, was correct, we have, from these observations, for the latitude of the *new* Observatory,

$$+ 38° 55' 14''.68.$$

On the assumption that the adopted longitude of the *old* Observatory, $5^h\ 8^m\ 12^s.04$ from Greenwich, is correct, we have, from this work, for the longitude of the *new* Observatory

$$5^h\ 8^m\ 15^s.71.$$

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ORBIT OF THE DOUBLE STAR *OΣ* 224.

PROFESSOR S. GLASENAPP.

This star has described arc of 60° since its first observation in 1842. Although such an arc is generally too small to give a good orbit, in this case we have to do with fairly good measures, and can obtain elements which may be considered as a sufficiently good approximation.

We have the following observations of *OΣ* 224:

t	θ °	ρ "	Observer	t	θ °	ρ "	Observer
1842.24	13.66	0.35	Mädler	72.28	333.4	—	Dembowski
44.31	20	—	OΣ	.31	336.8	0.55	OΣ
45.31	13.62	0.20	Mädler	74.22	323.4	—	Dembowski
51.27	352.6	0.48	OΣ	75.29	329.9	—	"
.28	17.52	0.25	Mädler	79.32	315.72	0.35	Schiaparelli
57.34	13.6	—	Secchi	80.16	334.3	0.62	Burnham
61.26	348.8	0.59	OΣ	81.25	316.66	—	Doberck
66.27	336.2	—	Dembowski	82.27	309.93	—	"
67.34	338.8	—	"	83.29	335.12	0.55	Engelmann
68.34	342.4	0.5	"	84.21	326.90	0.55	Perrotin
70.16	339.4	—	"	.27	323.70	0.52	Engelmann
71.13	332.4	—	"	87.27	315.59	0.53	Schiaparelli
.31	328.4	0.59	OΣ	92.37	313.6	0.48	Burnham

These observations are to be found in an article on OΣ 224 in ASTRONOMY AND ASTRO-PHYSICS, No. 108, by Professor S. W. Burnham.

We form simple arithmetical means for each year and plot these positions on millimeter paper, and draw a line through the points; we obtain $\Delta\theta$ for equal intervals Δt, and then the differential quotients $\frac{\Delta t}{\Delta\theta}$, from which we deduce the values of ρ by the formula:

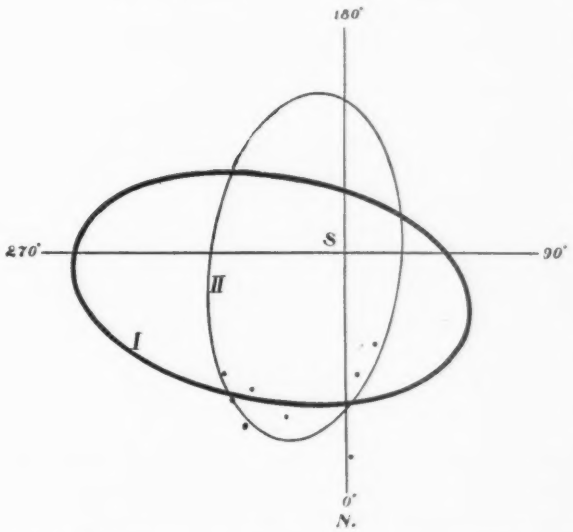
$$\rho = C\sqrt{\frac{\Delta t}{\Delta\theta}}$$

where C is an arbitrary constant. In this manner we obtain the following graphical positions of *OΣ* 224:

θ °	ρ	θ °	ρ	θ °	ρ
30	0.752	350	0.823	320	0.982
20	0.765	340	0.854	310	1.072
10	0.775	330	0.896	300	1.162
0	0.797				

If we lay down these positions on paper, we obtain the arc of an ellipse, whose centre may be easily found, and then the whole ellipse may be drawn. When this is made, we determine the co-ordinates of the intersection of the ellipse with the axis of co-ordinates, which are directed: $+X$ to $\theta = 0°$ and $+Y$ to $\theta = 90°$; thus we have obtained:

$x_1 = +0.796$ $\quad y_1 = +0.423$
$x_2 = -0.258$ $\quad y_2 = -1.302$



I. Apparent orbit of $O\Sigma$ 224. II. Ellipse of System II. Observed positions are dark round points.

By means of the formulæ which are given in my work "Orbites des étoiles doubles da Catalogue de Poulkove," St. Pétersbourg, 1889, namely:

$$\alpha = -\frac{x_1 + x_2}{x_1 x_2} \qquad \beta = -\frac{y_1 + y_2}{y_1 y_2}$$

$$\gamma = \frac{1}{x_1 x_2} \qquad \varepsilon = \frac{1}{y_1 y_2}$$

We deduce the values of the four co-efficients of the general equation of an ellipse:

$$\alpha x + \beta y + \gamma x^2 + \delta xy + \varepsilon y^2 + 1 = 0$$

We have obtained:

$$\text{Log } \alpha = 0.4183$$
$$\text{Log } \beta = 0.2031n$$
$$\text{Log } \gamma = 0.6875n$$
$$\text{Log } \varepsilon = 0.2591n$$

The fifth co-efficient will be determined by the co-ordinates x_3, y_3 of a point not lying on the axis of co-ordinates by means of the formula:

$$\delta = -\frac{1 + \alpha x_3 + \beta y_3 + \gamma x_3^2 + \varepsilon y_3^2}{x_3 y_3}$$

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We have determined δ by three points and have obtained an arithmetical mean:

$$\text{Log } \delta = 9.8616$$

From the formulæ of Kowolsky we obtained the following elements:

$$\begin{aligned} T &= 2031.71 \\ U &= 232.9 \text{ years} \\ n &= -1°.5459 \\ \Omega &= 73°.06 \\ \lambda &= 59°.64 \\ i &= 57°.95 \\ e &= 0.54 \end{aligned}$$

It appeared advisable to apply some corrections to these elements, and after forming equations of condition and solving them by the method of least squares, we found the corrected values of n, T and U:

$$\begin{aligned} n &= -1°.6096 \\ U &= 223\ .7 \text{ years} \\ T &= 2025.90 \end{aligned}$$

The semi-major axis was found from eight mean positions; $a = 0''.65$.

The following are the elements of $O\Sigma$ 224:

$$\left.\begin{aligned} T &= 2025.90 \\ U &= 223.7 \text{ years} \\ n &= -1°.6096 \\ \Omega &= 73°.06 \\ \lambda &= 59\ .64 \\ i &= 57\ .95 \\ e &= 0.54 \\ a &= 0''.65 \end{aligned}\right\} \quad \text{(I).}$$

On comparing computed and observed places it appeared that an improvement might be effected by giving the apparent orbit more curvature. A second apparent orbit was therefore found as indicated in the figure by the faint ellipse, while the elements (I) correspond to the apparent ellipse indicated by the heavy line.

$$\left.\begin{aligned} T &= 1976.81 \\ U &= 144.0 \text{ years} \\ n &= -2°.4997 \\ \Omega &= 175°.3 \\ \lambda &= 283°.7 \\ i &= 59\ .6 \\ e &= 0.433 \\ a &= 0''.52 \end{aligned}\right\} \quad \text{(II).}$$

After comparing the computed and observed places according to these two sets of elements, it appears that elements (I) will be the most probable at present obtainable.

COMPARISON OF THE ELEMENTS I WITH THE OBSERVATIONS.

t	ϑ_o	ϑ_c	$\vartheta_o - \vartheta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$	Observer.
	°	°	°	″	″	″	
1842.24	13.7	21.3	− 7.6	0.35	0.42	− 0.07	Mädler
44.31	20 ±	17.8	+ 2.2	——	0.42	——	OΣ
45.31	13.6	16.1	− 2.5	0.20	0.42	− 0.22	Mädler
51.27	352.6	6.1	− 13.5	0.48	0.43	+ 0.05	OΣ
.28	17.5	6.1	+ 11.4	0.25	0.43	− 0.18	Mädler
57.34	13.6	356.3	+ 17.3	——	0.44	——	Secchi
61.26	348.8	350.1	− 1.3	0.59	0.44	+ 0.15	OΣ
66.27	336.2	342.6	− 6.4	——	0.46	——	Dembowski
67.34	338.8	341.1	− 2.3	——	0.46	——	"
68.34	342.4	339.7	+ 2.7	0.5	0.46	+ 0.04	"
70.16	339.4	337.1	+ 2.3	——	0.47	——	"
71.13	332.4	335.8	− 3.4	——	0.48	——	"
.31	328.4	335.6	− 7.2	0.59	0.48	+ 0.11	OΣ
72.28	333.4	334.3	− 0.9	——	0.48	——	Dembowski
.31	336.8	334.2	+ 2.6	0.55	0.48	+ 0.07	OΣ
74.22	323.4	331.8	− 8.4	——	0.49	——	Dembowski
75.29	329.9	330.4	− 0.5	——	0.49	——	"
79.32	315.7	325.6	− 9.9	0.35	0.51	− 0.16	Schiaparelli
80.16	334.3	324.6	+ 9.7	0.62	0.51	+ 0.11	Burnham
81.25	316.7	323.3	− 6.6	——	0.52	——	Doberek
82.27	309.9	322.2	− 12.3	——	0.52	——	"
83.29	335.1	321.1	+ 14.0	0.55	0.53	+ 0.02	Engelmann
84.21	326.9	320.1	+ 6.8	0.55	0.53	+ 0.02	Perrotin
.27	323.7	320.0	+ 3.7	0.52	0.53	− 0.01	Engelmann
87.27	315.6	316.9	− 1.3	0.53	0.55	− 0.02	Schiaparelli
92.37	313.6	312.0	+ 1.6	0.48	0.57	− 0.09	Burnham

The position of the satellite during the next years will be found in the following ephemeris:

t	ϑ	ρ	t	ϑ	ρ
	°	″		°	″
1895.30	309.4	0.59	1915.30	294.4	0.69
1900.30	305.2	0.62	1920.30	291.3	0.71
1905.30	301.3	0.64	1925.30	288.4	0.73
1910.30	297.8	0.66	1930.30	285.6	0.75

In several years it will be possible to see which of the systems, I or II, is nearer to the real orbit. We give here a comparative ephemeris computed with the systems I and II:

EPHEMERIS OF $O\Sigma$ 224.

	Elements I.		*Elements II.*			*Elements I.*		*Elements II.*	
t	ϑ	ρ	ϑ	ρ	t	ϑ	ρ	ϑ	ρ
	°	″	°	″		°	″	°	″
1890.30	309.4	0.59	306.9	0.45	1915.30	294.4	0.69	269.4	0.37
1900.30	305.2	0.62	299.0	0.43	1920.30	291.3	0.71	258.0	0.37
1905.30	301.3	06.4	290.1	0.40	1925.30	288.4	0.73	246.6	0.37
1910.30	297.8	0.66	280.2	0.38	1930.30	285.6	0.75	235.5	0.48

Astronomers, possessing larger telescopes, should give attention to this double star. The position for 1880 is the following:

$$\alpha = 10^h\ 33^m.4$$
$$\delta = +9°\ 28'$$
$$\text{Mg} = 7.2 - 9.2$$

August 1893.

Astro-Physics.

THE TWO MAGNETIC FIELDS SURROUNDING THE SUN.*

FRANK H. BIGELOW.

It is my privilege, by permission of the chief of the U. S. Weather Bureau, to draw upon the material that has been acquired in an extended investigation of this subject, during the past two years, for some of the statements contained in this paper. Indeed the present reading is the first communication of part of the results to the public, though from time to time preliminary announcements of progress have been made.

The general subject has been one of deep interest to scientists, and much has been done toward its elucidation. The observed facts pertaining to solar physics, to terrestrial magnetism and to meteorology have been such as to render it very probable that these three distinct branches of science are in reality but parts of one more general, cosmical science. The periodic occurrences of manifestations of energy in the sun-spots, the solar corona, the faculæ, and the prominences, on the one hand; the aurora, variations of the terrestrial magnetic field, and fluctuations of the meteorological elements on the other, together with a few isolated observations of the spasmodic actions of the same, have all indicated a fundamental system of physical forces embracing the Sun and the Earth in its operation. The great distance separating these two members of the solar system from each other has, however, been raised as a barrier to the possibility of any such direct action of the Sun on the Earth, and therefore the Newtonian Law of Gravitation has alone been recognized as the bond of union, supplemented by the light radiations through the intervening ether. All the theoretical discussions as to the possibility of a magnetic influence of the Sun at the distance of the Earth have pronounced against the same, those who still hoped for the other verdict being able to sustain their conjectures only by some general statements regarding the electrical and magnetic nature of the Sun.

In spite of the rather unpromising aspect of the problem, I have for a number of years devoted my efforts to obtaining evidence for or against this cosmical relation between the Sun and the Earth through magnetic fields, being greatly incited to such work by the logical consequences of Maxwell's electro-magnetic theory

* Read at the Conrgess of Astronomy and Astro-Physics, Chicago, August, 1893.

of light, which apparently proven to be true by laboratory experimentation, must have other terrestrial manifestations than heat and light alone. For if the ether is capable of transmitting very rapid oscillating electric vibrations through 93,000,000 of miles it must be accompanied by the magnetic wave in quadrature, which from its great frequency would constitute a steady magnetic field of force, the axis parallel to the direction of the rays of light. If the Earth itself is a polarized magnetic sphere, immersed in such a field, the angles between the magnetic axis such as are determined by known astronomical relations, then the lines of force of this uniform field must be inflected to the Earth at certain angles, pass through it and leave the same at other proper exflected angles. If it were possible to disentangle this field from the permanent magnetic field, and to show its action as a whole, the result would be the long looked for solution of the problem of the variations of the diurnal and annual directions of the magnetic needle near the surface of the earth. It would necessarily be implied that such an electro-magnetic or radiant field has arisen in the atomic oscillations of the constituents of the photosphere of the Sun, communicating their vibrations to the ether, and propagating the radiant energy through it in accordance with mathematical laws that have been carefully examined.

Furthermore, if the Sun has a nucleus in which can reside a species of permanent magnetism, having poles of direction and intensity such as are found upon the Earth, it must also be surrounded by wide-sweeping lines of magnetic force, distributed in space according to another system of mathematical laws. The variations in the intensity of this field, due to heterogeneous distribution of magnetic masses within the solar nucleus, and the spasmodic intensifications of such magnetization, would necessarily vary the strength of this field in its several parts. Thus at the distance of the Earth, if the poles of magnetization of the Sun were found to be nearly perpendicular to the plane of the ecliptic, the lines of magnetic force would reach the Earth, also nearly perpendicular to the plane of the ecliptic, would enter the Earth concentrated at the polar magnetic zone in one hemisphere, pass through it in certain directions, and emerge from it on the other magnetic polar hemisphere. Upon such a curving magnetic field might be found such peculiar stream lines as are displayed in the coronal rays and rifts, allowing for the optical distortion due to their projection from a sphere upon a plane perpendicular to the line of vision; there might be found on these lines the impressed energy manifested in the auroral displays, in the terrestrial

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magnetic storms, in the periodic variations of the normal magnetic field that correspond to the rotation of the solar nucleus upon its axis; and finally it might be possible that the impressed energy of this magnetic cosmical field undergoes transformations that appear in synchronous variations of the atmospheric hydrostatic presure, temperature, relative humidity, electric potential fall, and general weather conditions, just as is well known to be the case with the transformations of the impressed energy of the electro-magnetic field. If all this were true then the Sun would generate two distinct magnetic fields, one from the photosphere and one from the nucleus; the former would pass through the ether by its rapid rectilinear vibrations in plane waves, and the latter by circular or vortical rotations within the ether, assuming this to be the correct view of what magnetic ether lines are; the Earth would then be traversed by at least three fields of magnetic force, the lines of permanent magnetism, those from the electro-magnetic or radiant field, and those from the magnetic or coronal field, the space just outside the surface of the Earth being penetrated by these three differently directed vector forces. In meteorology these two fields would be treated as two distinct types of solar radiation, one visible and heating, the other invisible and cooling the atmosphere, while both increase its hydrostatic pressure.

However fascinating such a view of the general problem may appear it must yet be made to depend absolutely upon the data of observation. The difficulties in opening the investigation were two in number, first, the currently accepted view that such a solar field as that from the nucleus would be too feeble for direct observation at the Earth; and second the disentangling of the observations, so as to show such systems of impressed forces deflecting the normal field of the Earth from its mean positions. It was very early perceived that in order to handle sucessfully the immense volume of data accumulated in magnetic and meteorological reports, only the very simplest process of computation could be employed, and that in fact the data must be treated quite independently of the theory just outlined, if the resulting values were to become immediately convincing to scientists. The remainder of this paper will therefore consist of a rapid review of the data employed and the results reached, these latter it may now be said, establishing the theory in a manner that it was not at the outset believed possible.

The methods of computation have already been fully explained in Bulletin No. 2 of the U. S. Weather bureau, "Notes on a New Method for the Discussion of Magnetic Observations," Washing-

ton, D. C., 1892. They consist essentially in taking out residuals in rectangular coördinates, the horizontal force giving the north component, the declination the west, and the vertical the inward in both hemispheres. These are then transformed into the equivalent polar coördinates, s the total force, σ its horizontal component on the plane of the horizon, β the azimuth angle of σ with the magnetic meridian, counted from the north through the west, and α the vertical angle between σ and s. The reports of magnetic observatories give these three coördinates tabulated for each of the twenty-four hours and for the calendar months. It was assumed that the diurnal variations, corresponding to the rotation of the Earth on its axis, were due to the forces of the electro-magnetic field, appropriate to a particular magnetic latitude and hour angle, which are impressed upon the normal field of the station. Therefore any station carried about by the Earth in its rotation is immersed in different parts of the impressed field in succession, whence it is only necessary to compute the deflecting forces, equivalent to the observed variations and transfer them simultaneously to a globe so placed as to maintain a steady position relatively to the field, in order to have the system which acts simultaneously over the Earth displayed to the eye. Of course it is not possible to obtain more than a mean result; to take account of the minute changes due to the eccentric position of the magnetic system of the Earth relatively to the axis of rotation, the changes of the Sun in declination in its annual period, and interpret the same at each station would demand a labor of computation impossible to undertake. It is at once seen that the electro-magnetic field being instantaneous in action, the observations of the last half century are available without reductions for secular changes of the field, and because the use of differential variations effectually eliminates the forces of the permanent terrestrial field. In the same way the variations of the mean daily values relatively to the mean of the month were assumed to be due to the action of the solar coronal magnetic field, and not to be merely accidental manifestations of variations due to instrumental errors and other agencies not fully understood. These residuals were treated in the same way, and the coronal field was thus eliminated from the permanent magnetic field of the Earth. The study of these two sets of residuals has fortunately served to clear up much that has been heretofore obscure in these subjects, and vistas of beauty have been opened which promise not only clearer views of the cosmical conditions, but also valuable practical results in several directions.

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The Radiant Magnetic Field.

The complex field due to the solar radiations has been computed for thirty stations, where continuous hourly observations in the three coördinates have been maintained for at least one year. The hourly means by months were employed so that twelve independent tables result for each station, and the mean for the year was also taken out. A model of the deflecting forces of the field was constructed on a 30-inch globe, where wires were inserted at the proper angle (β, α), and of such length that $1^{mm} = 0.00001$ dyne C G.S. There is a definite plan underlying the general system which shows at once that the law of magnetic refraction is fundamental, $\mu = \frac{\tan \omega}{\tan \theta}$; where ω is the angle of the ray in the denser magnetic medium, and θ in the rarer medium, with the normal at the surface of separation. The value of μ is about 1.25. The field is subdivided into three characteristic portions, the *polar* to a distance of about 28° from each magnetic pole, the *mid-latitude* in each hemisphere to magnetic latitude ± 30°, and the *equatorial*, embracing the tropical belt. They are each distinct from the others, and pass by abrupt changes from one to another. If an axis x is taken perpendicular to the plane of the ecliptic, positive towards the south, and y along the ecliptic positive towards the Sun, and z along the earth's orbit, positive in the direction to which it moves, the three fields, with a corresponding part in each hemisphere, form three couples of rotation acting on the earth. The *polar couple* turns the earth about the axis y anti-clock wise, the *mid-latitude couple* turns it about z clock-wise and the *equatorial couple* turns it about z anti-clock wise, thus opposing the mid-latitude couple. If one stands upright on the plane of the ecliptic, head on the north side, and looks out from the sun to the earth, the north polar field passes through the earth parallel to the ecliptic, from left to right, and south polar field from right to left; the north mid-latitude field enters the dark side of the earth and emerges toward the observer on the bright side, while the south mid-latitude field enters on the bright side, passes from the observer through the earth, and emerges on the dark side; the equatorial field pulls from the south to the north perpendicular to the ecliptic on the side of the observer, and from north to south on the dark side of the earth. The mid-latitude and the equatorial couples tend to balance each other, but the polar couple is distinctly alone. The south polar region, having no observatory nearer the pole than

Hobarton, is not represented fully, but it doubtless is the counterpart of the northern component. The north polar field shows a very peculiar system of forces, for it has a plane of symmetry turned at about 23° to the meridian passing through the sun, and near the axis are the apices of the two cones, built up by the vectors on the globe; from the one at the hour angle 4:30 A. M., the forces spreading about the polar hemisector and entering the earth; towards the other, at the hour angle 4:30 P. M. the forces emerging from the corresponding hemi-sector and tending to concentrate themselves. The surface integral of these polar systems is so disposed as to make it possible that the effective couple is destroyed, but if not it would form a term in the motion of the precession of the earth.

There is in the northern hemisphere a plane of symmetry at about the hour 10:30 A. M., where the declination component disappears, and the horizontal-vertical components are at a maximum; it shifts to about 11:30 A. M. in the southern hemisphere, and from it the forces flow away to the right and left hand as they enter the Earth. The lines of tangency, at which the vertical component disappears, are well marked, but are too complex in their course for description here. The places of transition from one part of the field to another show many abrupt changes in the vectors, which also manifest seasonal transformations in the annual period. The most marked abrupt change in the distribution is along the base of the polar cones at about 28° from the magnetic pole, separating the polar from the mid-latitude field, and also in a deep rift which divides the entering and the emerging halves of the polar field. A study of the model offers a satisfactory explanation of all the complex phenomena that have been so fully described in the literature of magnetic observations. The mathematical function corresponding to the polarized sphere plunged in a uniform field of force under these solar terrestrial astronomical conditions, has not been successfully worked out as yet, though the elements of the problem are obviously at hand. The further relation of these facts to the pure physics of electricity and magnetism offers a most fascinating subject of research, and one that is likely to assist in the solution of the great question as to the nature of the lines of force in the ether. It is evident that they are all in harmony with Maxwell's electro-magnetic theory of light, and may be regarded as important evidence in confirmation of the same. There is appended a table of vectors of the radiant field, taken from the globe-model, which has enabled me to smooth out certain indecisive parts of the record derived from the computations.

The Coronal Magnetic Field.

The attack upon the portion of the problem pertaining to the coronal magnetic field, has been conducted from two points, namely, the corona of the Sun, and the terrestrial field, believing that if its action could be detected at these two places, it must be at once conceded that its lines of force fill all the intermediate spaces between the Earth and the Sun with their characteristic curvatures. My results of study on the solar coronas of the eclipses of July 29, 1878, January 1, and December 22, 1889, have already been published.* If it is assumed that the stream lines of the corona are the lines of magnetic force seen in projection, then measured coördinates $(r.\theta.)$ of points on a single ray will give us the means of locating the ray in space. If

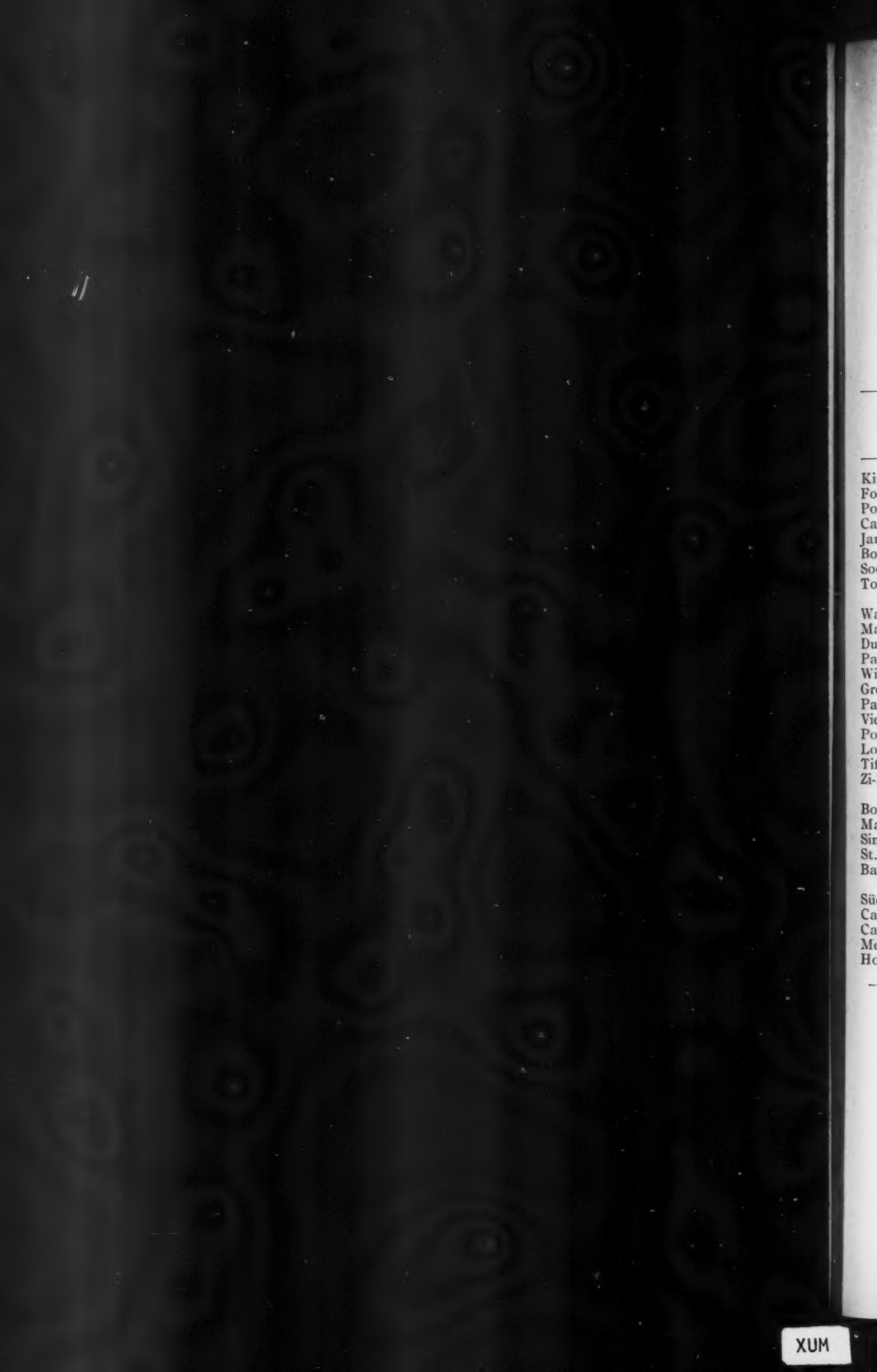
$$N = \frac{8\pi}{3} \cdot \frac{\sin^2\theta}{r},$$

is the equation of a stream line, and $x = r \sin \theta$, $y = r \cos \theta$, then by elimination from three points, the angle of projection separating the plane of vision through the center of the Sun and the plane containing the ray is approximately,

$$\sec^2\alpha = \frac{x_2^{\frac{4}{3}} y_1^2 - y_2^2 x_1^{\frac{4}{3}}}{x_1^{\frac{4}{3}} x_2^2 - x_2^4 x_1^2}.$$

Thence can be computed the magnetic polar distances of the bases of the rays, the location of the coronal poles on the surface of the Sun, and all the elementary distributions of the system, the strength of the magnetization being, of course, not attainable by the geometrical method. It has been found that the bases of the visible coronal rays are confined to two narrow belts, one in each hemisphere of the Sun, about 15° wide, with the middle parallel at about 34° of coronal polar distance. The magnetic poles are about 4½° in polar distance from the poles of the axis of rotation, the south coronal pole preceding the north coronal pole in longitude by about 102°. Having but three isolated points to work with, derived from the three eclipses, for the momentary location of these poles in space, and separated from each other by many rotations of the Sun, an attempt was made to determine the period of rotation of the Sun, even from such meagre data. The results there published have been entirely superseded by the method which will now be described. The har-

* 1. American Journal of Science, November, 1890. 2. American Journal of Science, July, 1891. 3. Publications of the Astronomical Society of the Pacific. Number 16, 1891.



DEFLECTING FORCES (

Measured fr

	Midnight.			1 A. M.			2 A. M.			3 A. M.			4 A. M.		
	s	α	β	*s*	α	β	*s*	α	β	*s*	α	β	*s*	α	β
Kingua Fjord	60	+40	140	60	+45	145	65	+50	155	73	+53	170	82	+55	180
Fort Rae	60	+39	150	62	+46	155	70	+52	165	76	+50	180	82	+50	190
Point Barrow	58	+38	155	64	+48	165	72	+50	175	80	+46	185	85	+44	195
Cap Thordsen	56	+37	160	68	+48	175	76	+45	185	82	+43	195	87	+42	205
Jan Mayen	58	+35	170	66	+45	185	74	+38	195	85	+40	205	89	+40	210
Bossekop	60	+32	185	64	+40	195	70	+34	205	75	+36	215	60	+35	220
Sodankyla	65	+31	195	58	+35	205	53	+30	215	48	+32	225	40	+30	235
Toronto	10	+30	255	10	+30	230	10	+25	225	14	+25	235	17	+25	240
Washington	18	−22	290	18	−30	290	18	−40	275	18	−40	275	18	−42	285
Makerstown	18	−24	295	18	−33	295	18	−42	270	18	−40	285	18	−44	290
Dublin	17	−27	300	18	−37	295	17	−44	265	17	−40	280	17	−46	290
Pawlowsk	17	−30	300	17	−40	295	17	−46	260	17	−44	270	17	−48	295
Wilhelmshaven	16	+25	305	14	+28	300	12	+27	290	13	+27	305	15	+26	305
Greenwich	16	+24	310	14	+29	300	12	+22	300	12	+30	305	14	+25	305
Paris	15	+23	310	14	+30	300	13	+21	305	12	+32	300	15	+24	305
Vienna	15	+25	305	13	+31	300	13	+20	300	12	+32	305	15	+27	305
Pola	13	+27	300	13	+32	305	12	+20	305	11	+32	305	12	+32	310
Los Angeles	13	+30	300	13	+34	310	12	+23	315	12	+34	310	14	+37	315
Tiflis	12	+35	300	13	+37	315	14	+30	320	15	+36	315	15	+38	310
Zi-ka-wei	9	+65	210	8	+65	225	9	+50	240	10	+42	250	11	+40	240
Bombay	23	+35	185	22	+35	190	22	+40	185	22	+46	180	21	+43	185
Madras	21	+35	185	22	+32	195	23	+37	185	21	+45	180	20	+40	185
Singapore	20	+35	190	21	+33	200	22	+35	190	21	+43	185	20	+35	195
St. Helena	18	+32	185	16	+32	200	18	+35	190	20	+40	190	17	+33	195
Batavia	16	+30	180	14	+30	195	16	+35	185	18	+35	195	13	+30	190
Süd Georgien	20	−30	70	20	−30	65	18	−30	65	17	−30	60	19	−30	50
Cape Horn	20	−28	75	20	−30	70	18	−32	70	19	−34	65	21	−34	45
Cape Good Hope	20	−27	80	20	−32	70	19	−35	70	19	−36	65	20	−37	45
Melbourne	18	−26	85	18	−32	70	17	−37	75	19	−38	65	20	−38	45
Hobarton	16	−26	85	16	−33	75	15	−40	75	17	−40	60	20	−40	45

s. Units of 6th decimal.

α. Positive ang

RCES OF THE RADIANT MAGNETIC FIELD,

ured from the 30-inch Globe-Model.

A. M.		5 A. M.			6 A. M.			7 A. M.			8 A. M.		
α	β	s	α	β	s	α	β	s	α	β	s	α	β
-55	180	92	+52	185	93	+50	190	92	+47	195	87	+45	200
-50	190	88	+50	195	94	+50	195	100	+46	200	90	+39	205
-44	195	92	+45	205	98	+45	205	105	+42	210	88	+37	215
-42	205	91	+40	210	93	+40	210	88	+39	215	75	+36	225
-40	210	89	+40	215	90	+35	215	75	+37	220	55	+34	235
-35	220	50	+35	225	46	+33	230	40	+35	230	35	+33	245
-30	235	35	+30	235	33	+30	240	30	+33	245	27	+32	250
-25	240	19	+25	245	21	+30	280	26	+30	285	26	+30	270
-42	285	18	−43	295	19	−33	290	21	−26	285	24	−20	275
-44	290	19	−44	295	20	−34	295	22	−29	285	24	−25	275
-46	290	19	−45	290	21	−36	295	23	−31	285	25	−28	280
-48	295	19	−46	295	22	−38	295	24	−33	285	26	−30	275
-26	305	16	+24	300	18	+23	300	23	+22	285	26	−25	270
-25	305	16	+21	300	18	+25	300	23	+23	285	26	−23	275
-24	305	16	+19	300	18	+27	305	21	+24	300	24	+20	285
-27	305	18	+21	305	25	+28	310	22	+27	305	24	+22	290
-32	310	15	+27	305	19	+29	310	21	+30	305	24	+23	290
-37	315	17	+31	305	19	+30	305	21	+32	310	25	+25	295
-38	310	17	+36	305	19	+32	295	21	+35	295	25	+28	285
-40	240	13	+40	225	15	+35	210	18	+35	220	22	+30	260
-43	185	20	+40	185	22	+37	185	23	+36	165	23	+30	140
-40	185	20	+38	190	22	+36	185	23	+35	165	23	+29	130
-35	195	19	+37	190	19	+35	185	20	+37	160	24	+29	120
-33	195	16	+35	185	18	+35	185	20	+39	155	24	+31	105
-30	190	12	+33	180	15	+35	180	20	+40	150	25	+33	90
-30	50	21	−30	45	24	−32	40	26	−28	50	27	−30	65
-34	45	22	−32	45	24	−30	45	26	−26	55	28	−27	70
-37	45	23	−34	45	25	−30	45	27	−23	55	29	−26	70
-38	45	21	−35	40	23	−30	40	25	−21	55	26	−27	70
-40	45	21	−36	40	22	−32	40	25	−20	60	28	−30	65

itive angle below the horizon. β. Azimuth i

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ELD,

8 A. M.			9 A. M.			10 A. M.			11 A. M.			Magnetic Latitude
s	α	β	s	α	β	s	α	β	s	α	β	
87	+45	200	82	+37	205	58	+40	210	66	−50	350	+78°
90	+39	205	78	+40	210	52	+43	220	64	−48	350	76
88	+37	215	65	+43	220	43	−43	340	50	−46	0	73
75	+36	225	50	+37	230	38	−50	345	43	−43	10	71
55	+34	235	40	+34	235	28	−50	350	40	−40	15	69
35	+33	245	33	−33	325	26	−38	330	38	−35	20	65
27	+32	250	27	−32	310	26	−40	285	28	−45	80	62
26	+30	270	26	−30	300	26	−40	250	25	−50	145	61
24	−20	275	27	−25	250	29	−35	230	23	−44	130	56
24	−25	275	26	−23	245	28	−32	225	23	−39	125	55
25	−28	280	26	−22	245	26	−30	225	24	−37	120	55
26	−30	275	27	−22	240	26	−32	225	24	−39	120	54
26	−25	270	27	−19	245	27	−35	225	26	−40	125	51
26	−23	275	27	−18	245	27	−35	225	27	−35	125	50
24	+20	285	26	−20	245	27	−36	225	27	−33	130	47
24	+22	290	26	−21	240	27	−38	225	27	−32	135	45
24	+23	290	26	−22	240	27	−38	230	27	−33	135	42
25	+25	295	27	−24	235	26	−39	235	26	−35	140	40
25	+28	285	27	−27	235	27	−41	230	27	−38	140	36
22	+30	260	23	−42	230	23	−44	225	24	−34	145	28
23	+30	140	24	−28	40	34	−28	20	43	−27	10	10
23	+29	130	24	−25	45	35	−30	25	44	−24	20	+ 4
24	+29	120	27	−23	50	37	−27	30	45	−22	25	− 6
24	+31	105	28	−21	50	35	−22	35	45	−20	30	−11
25	+33	90	28	−20	55	33	−19	40	40	−18	35	−15
27	−30	65	28	−35	75	28	+30	115	27	+35	150	−30
28	−27	70	29	−35	75	28	+30	120	27	+37	150	−33
29	−26	70	30	−33	80	28	+25	120	26	+40	150	−34
26	−27	70	27	−32	75	26	+23	115	24	+38	145	−50
28	−30	65	27	−30	75	25	+25	110	23	+35	140	−55

β. Azimuth in the direction N. W. S. E.

	Noon			1 P. M.			2 P. M.			
	s	α	β	*s*	α	β	*s*	α	β	*s*
Kingua Fjord	74	−51	355	85	−52	0	93	−53	10	94
Fort Rae	72	−48	0	75	−49	10	80	−50	15	89
Point Barrow	63	−46	5	68	−45	15	76	−45	20	87
Cap Thordsen	57	−42	15	68	−42	20	76	−40	20	90
Jan Mayen	54	−39	20	62	−39	25	75	−37	25	90
Bossekop	48	−36	30	55	−36	35	70	−35	35	80
Sodankyla	27	−35	75	35	−34	60	44	−30	55	52
Toronto	20	−35	120	27	−30	110	26	−25	70	26
Washington	30	−35	115	31	−26	105	29	−24	90	27
Makerstown	30	−32	115	31	−24	100	29	−21	90	27
Dublin	32	−34	110	31	−22	100	29	−18	90	27
Pawlowsk	32	−35	110	32	−20	100	30	−17	90	27
Wilhelmshaven	35	−37	115	34	−20	105	30	−18	95	25
Greenwich	37	−35	110	36	−20	100	33	−19	95	25
Paris	38	−35	105	36	−21	100	33	−20	95	26
Vienna	36	−33	105	35	−22	100	30	−22	95	26
Pola	35	−34	105	33	−25	100	30	−25	95	25
Los Angeles	35	−35	105	33	−30	100	30	−26	95	25
Tiflis	35	−37	100	33	−36	90	30	−29	85	24
Zi-ka-wei	27	−42	75	26	−45	45	23	−30	65	20
Bombay	44	−27	15	40	−33	345	37	−30	340	19
Madras	44	−28	15	40	−32	345	35	−28	340	18
Singapore	44	−30	15	40	−30	345	33	−26	335	17
St. Helena	43	−32	10	40	−30	340	32	−25	335	15
Batavia	41	−35	10	38	−30	340	32	−25	330	15
Süd Georgien	30	+45	220	31	+40	230	32	+35	240	32
Cape Horn	30	+43	225	32	+38	230	32	+36	245	30
Cape Good Hope	28	+40	230	30	+35	230	30	+37	250	30
Melbourne	27	+40	230	32	+33	235	30	+38	260	30
Hobarton	25	+35	230	33	+35	240	28	+37	265	30

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DEFLECTING FORCES OF THE RADI ANT M

Measured from the 30-inch Globe-

2 P. M.			3 P. M.			4 P. M.			5 P. M.				6 P. M.
s	α	β	s	α	β	s	α	β	s	α	β	s	α
3	−53	10	94	−50	15	93	−47	15	90	−44	20	80	−42
0	−50	15	89	−46	20	94	−45	20	90	−41	25	82	−40
6	−45	20	87	−42	25	94	−42	25	95	−38	30	83	−37
6	−40	20	90	−39	25	100	−38	25	97	−34	30	86	−36
5	−37	25	90	−36	25	102	−34	25	94	−30	30	84	−36
0	−35	35	80	−33	30	84	−33	30	83	−30	30	72	−35
4	−30	55	52	−30	45	58	−32	40	62	−32	35	60	−34
6	−25	70	26	−28	60	24	−30	55	18	−40	40	14	−43
9	−24	90	27	+23	70	25	+40	50	23	+42	45	21	+58
9	−21	90	27	+24	75	26	+42	60	24	+44	50	24	+60
9	−18	90	27	+24	80	26	+40	65	24	+44	55	24	+58
0	−17	90	27	+22	85	25	+39	70	23	+42	65	22	+56
0	−18	95	25	+20	95	21	+40	80	19	+42	75	19	+54
3	−19	95	25	+19	95	21	+40	80	18	+45	85	18	+54
3	−20	95	26	+18	95	22	+38	80	18	+44	90	17	+56
0	−22	95	26	+18	100	22	+37	85	18	+42	90	16	+55
0	−25	95	25	+20	95	21	+37	90	17	+45	95	13	+56
0	−26	95	25	+22	95	21	+38	90	17	+47	100	12	+58
0	−29	85	24	+27	90	20	+42	110	16	+50	110	12	+60
3	−30	65	20	+45	50	13	+48	115	15	+54	140	16	+32
7	−30	340	19	−32	315	16	+30	225	15	+35	195	17	+27
5	−28	340	18	−30	305	17	+32	220	16	+30	195	18	+24
3	−26	335	17	−28	300	17	+32	220	17	+25	200	19	+22
2	−25	335	15	−28	295	16	+30	220	16	+20	200	19	+20
2	−25	330	15	−28	290	16	+30	215	17	+15	200	20	+18
2	+35	240	32	+30	260	28	−30	270	24	−40	265	21	−40
2	+36	245	30	+35	260	29	−30	275	25	−40	270	21	−40
0	+37	250	30	+30	260	28	−25	275	25	−38	275	20	−40
0	+38	260	30	+30	265	27	−30	275	24	−37	280	20	−40
8	+37	265	30	+35	265	26	−35	280	21	−40	280	19	−40

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ANT MAGNETIC FIELD,

Globe-Model.

6 P. M.		7 P. M.			8 P. M.			9 P. M.			10 P. M.			11 P. M.			Magnetic Latitude
α	β	s	α	β	s	α	β	s	α	β	s	α	β	s	α	β	
−42	20	68	−40	25	58	−35	30	55	−32	30	52	−28	30	44	+38	135	+78°
−40	25	70	−37	25	60	−34	30	56	−31	40	54	−24	40	52	+40	140	76
−37	30	72	−36	30	62	−36	35	57	−27	50	54	−20	45	52	+42	145	73
−36	30	70	−34	30	60	−38	40	55	−23	60	55	+25	130	56	+40	150	71
−36	30	60	−33	35	57	−33	45	53	−20	65	53	+30	140	57	+38	160	69
−35	35	50	−30	40	45	−27	45	43	+28	140	44	+30	150	50	+34	180	65
−34	35	42	−25	40	37	−22	50	38	+28	145	40	+30	155	47	+30	185	62
−43	30	10	−44	50	9	−30	45	9	+35	330	8	+28	300	7	+20	270	61
+58	25	20	+56	340	19	+34	310	18	+40	300	17	+24	300	17	−24	295	56
+60	20	22	+53	330	20	+37	305	18	+37	295	17	+22	295	16	−22	300	55
+58	20	21	+48	325	20	+40	305	19	+38	290	18	+22	290	16	−20	300	55
+56	15	21	+45	320	19	+40	310	18	+38	290	17	+27	295	16	−20	300	54
+54	25	19	+40	315	19	+42	310	19	+39	300	19	+30	300	17	+32	305	51
+54	30	19	+38	320	19	+44	310	18	+37	305	19	+35	305	18	+30	305	50
+56	35	17	+38	325	17	+46	315	17	+35	310	17	+38	305	17	+27	305	47
+55	45	16	+40	335	15	+42	310	14	+36	305	15	+39	300	15	+33	305	45
+56	55	11	+45	50	10	+40	295	10	+38	300	9	+41	295	8	+45	300	42
+58	115	11	+47	105	9	+42	140	9	+40	255	9	+45	290	8	+48	295	40
+60	125	12	+44	140	10	+43	150	9	+45	220	8	+53	230	8	+50	240	36
+32	155	18	+40	160	16	+40	175	10	+50	185	10	+60	180	9	+55	180	28
+27	195	19	+30	180	21	+33	180	21	+35	180	20	+33	180	20	+30	185	10
+24	195	21	+30	180	22	+30	180	22	+33	180	23	+30	180	24	+30	185	+ 4
+22	190	21	+30	185	23	+28	180	24	+30	180	24	+27	185	24	+28	190	− 6
+20	190	22	+30	185	24	+28	185	25	+27	175	24	+25	185	24	+25	185	−11
+18	190	22	+30	185	23	+30	185	24	+25	175	24	+25	190	24	+25	185	−15
−40	255	18	−45	215	18	−50	185	20	−50	120	20	−45	100	20	−35	90	−30
−40	255	18	−45	225	18	−46	185	18	−48	125	18	−40	100	18	−35	90	−33
−40	260	18	−45	240	18	−45	190	17	−45	130	18	−40	100	18	−35	85	−34
−40	270	17	−45	300	16	−45	350	16	−45	55	17	−40	70	18	−35	75	−50
−40	280	16	−44	310	16	−46	350	16	−45	65	17	−40	75	17	−38	80	−55

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monious relation of all the complex formations of rays and structure to the simple law of magnetic lines of force surrounding a polarized sphere, is such as to render it extremely probable that this is the fundamental law of the corona, from which follows much regarding the constitution of the Sun. If however, it is possible to detect the direct action of these same rays at the Earth's magnetic field, this argument regarding the Sun and the cosmical transmission of energy will attain a safe position for further deductions.

Returning now to the variations of the terrestrial magnetic field, the residuals of the means of the twenty-four observations of each day relatively to the normal mean, derived from the annual mean corrected for the mean of the months, were considered and combined into polar coördinate deflecting forces, just as was done for the radiant field. Certain characteristics at once emerged into view which have enabled me to make important progress in this investigation. Seven European stations for the year 1886, and four more for the year 1887 were completely reduced and the values of s, σ, α, β, tabulated side by side throughout the year. An inspection of the 1886 table showed that certain systematic periodic changes were recurring in about 27 days. Especially was this clearly seen in the azimuth angles which passed through changes of 180° at certain individual dates. The seven stations scattered over Europe, Greenwich, Paris, Pola, Prague, Vienna, Pawlowsk, Tiflis, exhibited deflecting forces pointing north along the magnetic meridians, which would all turn to the south within the same twenty-four hours. There are many other local and sub-periodic characteristics which it must be omitted to describe in this brief paper. In order to prove that these azimuth reversals are cosmical, two stations in America, Los Angeles, California, and Toronto, Canada, were added, as well as Zi-ka-wei, China, and Batavia, Java, covering the hemisphere, and it was found that these simultaneous and periodic reversals of the deflecting forces were entirely independent of longitude. Furthermore on discussing the corresponding vertical angles α, in spite of their fluttering and uncertain directions at individual stations, arising chiefly from the lack of sensitiveness of the balance magnetometers, it was found that the mean values of α are such that when the field deflects southward, these forces enter the Earth at an angle of about 41°, and that when pointing north they emerge also at 41°. A comparison of the total force s with the horizontal component shows that these vary together in parallel, and are due to

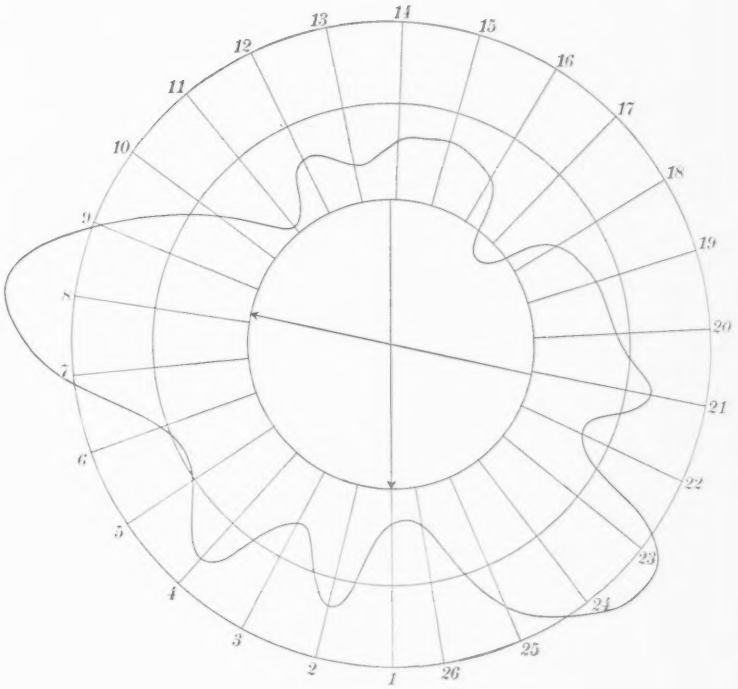
the same force, making a mean angle in Europe of 41° with the horizon. A simple process shows that this field is cosmical and approaches the Earth perpendicular to the ecliptic, but is therefrom deflected by the laws of magnetic conduction to enter the Earth within about 7° of the Earth's axis of rotation. The period of the total change was found to be 26.68 days with an epoch, 1887, June 12.22. The period has a series of minor fluctuations in it which I have been able to determine very carefully, and which correspond to an alternate strengthening and weakening of the normal terrestrial field on each side of a mean value.

In order to test the persistence and peculiarities of the resulting curve of variable intensity, such computations were continued for 12 years, from 1878 to 1889 inclusive, for European stations, and all combined by means of an ephemeris constructed from the epoch and period. The following curve is directly obtained by this process. The mean curve has double maxima, on the 17th and 26th days, and double minima, on the 7th and the 24th days.

It shows maximum crests on the 3d, 6th, 11th, 13th, 17th, 22d and 26th days, with corresponding hollows between them. Generally there is a diminution in the intensity between the 3d to the 11th days, and again between the 22d to the 26th, with a stronger field from the 11th to the 22d. Now my dates of reversals were such as to divide up the 26.68 day period into two parts, one of about 8 days and the other of about 19 days, and on reducing these intervals carefully to degrees it gave 102°, as the main sub-division in effectiveness of the period, which agrees so closely with the 100° that had been obtained from the coronal studies, as to render it probable that the same forces were behind the distribution of magnetism on the Sun and this periodic variation of the field at the Earth. Indeed it is only necessary to suppose that the solar nucleus is permanently magnetized, rotates on its axis synodically in 26.68 days, and that this field is swept along past the Earth, the variable intensities being impressed upon the Earth's field and thus detected by the observations.

In order to strengthen this point of view a series of applications of this coronal period have been made with the following results. From four least square discussions of the periodic azimuth changes for the dates corresponding to the 3d, 11th, 17th, and 22d days, the mean correction to the trial period is —0.00072 day, the data embracing the year 1878 to 1889 inclusive. The final period is 26.67928 days $= 26^{d}\ 16^{h}\ 18^{m}\ 9.8^{s}$, and the corresponding sidereal period is $24^{d}\ 20^{h}\ 42^{m}\ 59.6^{s}$. This gives the mean

PLATE XXXVIII.



Variation of the intensity of the **CORONAL FIELD**
in the 26.68 day period, at the EARTH.
MIDDLE CIRCLE = 0.000115 *dyne;*
increase towards Centre.

daily motion 868′.7, and is the rate of rotation of the external magnetic field, from whence it is inferred that this is the angular velocity of the nucleus of the sun. From the motion of Sunspots on the surface it has been computed that at the equator the velocity is 863′ (Faye), 858′ (Tisserand), 878′ (Spoerer), which agree so closely with the value derived from the coronal field as to force the conclusion that they are measures of the same quantity. Since the magnetic lines of force which reach the earth leave the surface of the sun within 4° of the magnetic poles, it seems probable that the polar and the equatorial regions of the Sun rotate with the same velocity. Hence the so-called acceleration of the equatorial belt of the Sun's surface is only a relative motion as compared with the Sun-spot belts, the true phenomena being that these spot-belts are a westward (anti-rotational) current drift analogous to the terrestrial surface trade winds of the tropics, and due to a general circulation of the Sun's fluid materials.

By means of the ephemeris a model of the stream lines of the solar corona, constructed in accordance with the theory, can be placed in such a position as the sun occupied relatively to the earth at the time of the three eclipses, assuming only that the first day of our period is the time of the south coronal pole being in the plane perpendicular to the ecliptic, and containing the sun and the earth. When so placed the shadow of orthogonal projection on a plane gives such a picture as the corona should present at the eclipse. The stream lines measured up for computation were enlarged to the model size, copied on transparent paper, and eclipse and model pictures compared directly. The agreement even in details of distribution is a strong proof of the soundness of the theory and the computed period. On wrapping the coronal curve, (see diagram) about a pole, the axes of the locus are seen to be such as already derived, namely at about 102° from the south to the north coronal pole. This is however a problem that is subject to rigorous computation. Many obvious inferences regarding this view of the constitution of the sun might be drawn, and their applications to certain current theories of the sun, its envelopes, the interplanetary spaces and the action of the same on comets and meteorites, but these must here be omitted.

The application of this coronal period to other phenomena is such as to confirm beyond a reasonable doubt these views regarding its formation and the manner of its operation in solar-terrestrial physics. Thus the Greenwich sun-spot areas give the the same fundamental curve, for the years 1878 to 1889 inclusive.

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The auroral frequencies taken by stations reporting in the "Monthly Weather review" for 1885–1888 give the same, but less exactly. From the discussion of all the magnetic disturbances of Washington, D. C., for 1889, 1890, 1891, the great impulses all come upon the Earth from north to south, along the coronal field. The same is strikingly shown by the results of the discussion of the magnetic storms, Jan. 4, 5, Jan. 28, 29, Feb. 13, 14, 1892, from ten widely separated stations. The potential-fall of atmospheric electricity from Mendenhall's observations, seven stations, 1886, 1887, taking only clear and fair days, gives the same general curve. Applying it to the meteorological elements, four years at the same European stations, 1886–1889, give a synchronous barometric pressure, with range of ± 2 mm. annually, and directly proportional to the variations of magnetic intensity; the temperatpre varies inversely to the magnetic force in the annual mean of about ± 0°.5 C.; the relative humidity varies inversely about 1.5 %. From counting the numbers of Highs and Lows on the International Charts of 1883 and 1887, the member increases about 20 % with the range of the period. From the U. S. Weather Maps for fifteen years, 1878–1892, it appears that the maximum barometric pressures and the minimum pressures vary with the magnetic field in the 11-year period and also in the coronal period. From the synoptic charts of the North Atlantic for 10 years, 1878–1887, it is found that the hydrostatic pressure of the permanent cyclone decreases with the magnetic period, indicating an action upon the whole atmosphere. From the International Polar Stations of 1882–1883, and the Siberian observations of the same period for the twelve stations, this direct variation of hydrostatic pressure is found more marked, and that too outside the ordinary storm tracks. From tabulations of the weather intensities on a scale of 4, for Europe two years, Washington, D. C., ten years, 1883–1892, Chicago five years, 1888–1892, Bismack, 1888–1892, it is seen clearly that storms tend to accumulate about the maxima of the magnetic curve, and that especially after the 3d, the 11th, the 17th, 22d and the 26th days, the severe weather conditions are most frequent. Herein is an admirable source of long range weather predictions in general terms. The two uncertain factors are *first*, the irregular workings within the Sun's nucleus, and *second*, the lack of uniformity with which this impressed energy coming upon the polar regions bursts forth into the cyclonic systems of the lower latitudes. I have no doubt that much of the difficulty of the solar irregularity can be met by a close watch upon the coronal

field through magnetic instruments, especially as the readjustments of magnetism within the nucleus go on with a leisurely pace, judging from the work on these last fifteen years. The second difficulty, as to localizing the outbursts of energy can be met only by a much better knowledge of meteorological physics than we now possess, but the symptoms of change of energy on the daily maps are often apparent to the eye. That the meteorological system is somewhat dependent upon the coronal magnetic field hardly admits of further doubt, and consequently there is ground for some modification of the current theories of storms. This point will be explained before section G. of Meteorology, Congress Auxiliary of the World's Fair.*

In conclusion the radiant electro-magnetic field gives a magnetic strength acting on a unit positive pole of about 0.000135 dyne C.G.S. The mean horizontal component of the coronal field is 0.000085, C.G.S., and of the total force about 0.000115 C.G.S. at the Earth and the variations 0.000040 C.G.S. Hence the intensity of magnetization of the Sun is about 2,340,000 times as much, or 269 dynes, C.G.S. The maximum intensity of magnetization of steel is 1390 dynes (Rowland), hence the normal magnetism of the Sun is about one-fifth that of the maximum of steel. This in the case of ordinary disturbances rises to 4 or 5 times as much, in the most violent to 50 times as much, namely, to 10 times that of the maximum steel. From these data the whole magnetic system of the Sun can be computed, and thence much can be deduced relatively to cosmical propagations of energy, hitherto inaccessible to us. This brief paper cannot do justice to the strength of the proof of the many points compressed into it, but the knowledge of the computations leads me to say that while the forces of these two magnetic fields act in a fluttering way, as is commonly known, yet the action is persistent and accumulative in impressing their forces upon ponderable matter, by the linear or rotational radiant forms of energy. Therefore from the Sun come to the Earth two great supplies of energy, both types of radiations through the ether and possessing very different properties, the one visible to the eye, the other visible to magnetic perceivers.

* See American Meteorological Journal for September, 1893.

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THE CONSTITUTION OF THE STARS.*

EDWARD C. PICKERING.

Our only knowledge of the constitution of the stars is derived from a study of their spectra. This has been done at the Harvard College Observatory as a portion of the work of the Henry Draper Memorial. Photographs have been taken of the spectra of the brighter stars on a large scale, some of them being as much as six inches in length. To photograph the fainter stars, a smaller dispersion is employed and in this way the spectra of stars as faint as the ninth or even the tenth magnitude may be obtained. To study the stars too far south to be visible in Cambridge, expeditions have been sent to South America, and a permanent observing station has been established near Arequipa, Peru, at an altitude of about eight thousand feet. There the southern stars are photographed with instruments similar to those used in Cambridge for the northern stars. A few spectra have been photographed with plates stained with erythrosin, which renders them sensitive to the yellow rays. A portion of the visual spectrum not shown on an ordinary plate is thus photographed. Images of the sodium line "D" in which the two components are clearly visible have been obtained for several stars. In all, many thousand photographs have been collected, including stars in all parts of the sky, from the north to the south pole. The spectra of all the bright stars have been photographed as described above, with a large dispersion, and the spectra of a large portion of the faint stars with a small dispersion. A careful study has been made by Mrs. M. Fleming of the fainter stars, and of the brighter stars by Miss A. C. Maury. From this it appears that while at first sight many spectra seem to be unlike, nearly all of them can be arranged according to a simple system. It is not proposed in the present paper to consider the cause of these differences. For purposes of description, it will be convenient to treat them as if due to differences in composition only, although there is evidence that the actual variation is rather in the order of growth. The spectra of ninety-nine one hundredths of the stars could be imitated by combining in different proportions four sets of lines. These are first, hydrogen; second, a substance presumably calcium in such a condition that it gives the broad lines "H" and "K" which

* Read at the Congress of ASTRONOMY AND ASTRO-PHYSICS, Chicago, August, 1893.

are the most marked features in photographs of the solar spectrum; thirdly, the substance, or substances, which give the lines characteristic of many of the bright stars in Orion; fourthly, the lines of the solar spectrum omitting those due to hydrogen and calcium. These four classes of lines may be described as hydrogen, calcium, Orion and solar lines. We may now arrange nearly all the visible stars in a sequence such that the spectra change insensibly from each one to the next. At one end of this sequence are such stars as α Virginis, α Eridani, and β Canis Majoris. In them, the Orion lines and hydrogen lines are well marked. The principal Orion lines have wave-lengths 382, 402 and 453, and are sometimes nearly as intense as the hydrogen lines. These spectra are designated by the letter B in the provisional classification adopted in the Draper Catalogue. In the next stars of the sequence the Orion lines have become fainter and the hydrogen lines stronger while the calcium and solar lines are faintly seen. This gives the large class of stars called A in the Draper Catalogue, of which the Milky Way is mainly formed. The stars α Canis Majoris and α Lyræ are examples of this class. The hydrogen lines here so greatly exceed all the others in intensity that in faint spectra they are the only lines visible. The line "H" due to hydrogen has a slightly greater wave-length than the corresponding line due to calcium. When these lines are well defined and about equally intense the H line appears double. This is well shown in such stars as α Cygni in which the hydrogen lines are narrow, but is also distinctly seen in good spectra of α Lyræ and other normal first type stars. In some stars such as α Aquilæ the hydrogen and other lines are broad and ill defined as if the spectra were out of focus. It is possible that this is due to a rapid revolution of the stars around their axes by which the portion near one edge would be receding while that near the opposite edge is approaching. But the velocity required, about a hundred miles a second in the case of α Aquilæ, is so great that such a hypothesis must be accepted with caution. The calcium and solar lines now gradually increase, and the Orion lines diminish in intensity, until they disappear; the hydrogen lines "G" and "h" also diminish. This class of spectrum is called F in the Draper Catalogue. The K line is as intense as the H line and the h and G lines are distinctly fainter. The stars α Argus (Canopus) and β Cassiopeiæ are examples of this class. The solar lines now steadily increase in intensity and the hydrogen lines diminish until the latter are no more intense than some of the solar lines. The typical second type stars are here reached and are represented by α Auri-

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gæ, α Centauri, and α Ursæ Minoris. They are called G in the Draper Catalogue or E if so faint that only the principal lines are visible. Before reaching this point we may have the hydrogen and solar systems of lines both strong as in α Canis Minoris. It is therefore difficult to decide whether both substances are combined in a single star, or whether the star is a close double, one component having a spectrum of the first, the other of the second type. This combination often occurs in double stars. In fact it has long been noticed that in the case of double stars, the brighter component is frequently of a reddish, the fainter of a bluish tint. The spectrum of the first star is then often of the second, while that of that of the second star is of the first type.

The photographs of the prismatic spectra so far described have a uniform density from the F to the H lines, that is from wave-length 397 to 486. As we progress in the series the density of the portion of the spectrum of greater wave-length increases as compared with the other portion. With sufficient dispersion the spectrum is seen to undergo a sudden diminution in density as the wave-length diminishes at the point whose wave-length is 430. The difference in brightness becomes more marked, as the dispersion diminishes, so that when the dispersion is small very faint stars of this class may be recognized by their short spectra, the portion whose wave-length is less than 430 not being visible. Probably the classification of spectra may be carried to fainter stars by means of this property than by any other. The letters H, I, and K are used in the Draper Catalogue to designate such stars. Their spectra may be regarded as forming a second division of the second type. The Sun and α Boötis are striking examples of this class, and α Tauri is a star still further advanced in the series. As we progress in the sequence a second sudden change in intensity takes place at the point whose wave-length is 476. Unlike the other change the intensity of the portion of shorter wave-length here exceeds that of greater wave-length. This may be regarded as the distinctive feature of the photographic spectra of stars of the third type. The brighest star of thisclass is α Orionis. The letter M is used to designate spectra of the third type in the Draper Catalogue. These stars may be further subdivided into four classes, of which the first is that just described. The second is represented by α Herculis in which the spectrum is distinctly banded, each band having its edge of greater wave-length bright. The third class is not represented by any bright star. Many of the variable stars of long period have this spectrum when they are not near their maxima. Variable

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stars of long period, when near maxima, constitute the fourth division which differs from the third only in having one or more of the hydrogen lines bright.

Two classes of spectra must now be considered which are not provided for in the above classification. The first of these consists of the spectra of gaseous nebulæ, the second, that of the stars whose spectra consist mainly of bright lines. The wave-lengths of the lines in both of these classes of spectra appear to coincide with those of the Orion and hydrogen lines. They therefore appear to precede the Orion stars in the sequence described above, but the lines are bright instead of dark. While an ordinary star may be regarded as having a bright nucleus giving a continuous spectrum surrounded by an absorbing medium, the bright nucleus in these objects is wanting, and the spectrum appears to be directly due to the incandescent gas. The reversal in brightness may thus be explained. The gaseous nebulæ can be divided into at least two classes and the bright-line stars into at least three. A few other stars have one or more bright lines in their spectra; for instance, such stars as γ Cassiopeiæ, and φ Persei in which the F line is bright. They generally belong to the Orion class, and probably so much hydrogen is present in their atmospheres that the absorption is overbalanced by the direct light of the gases.

One other class of spectra remains, that of stars of the fourth type. Their spectra appear to be identical with that of carbon. Almost sixty of these objects are known. They are intensely red and therefore difficult to study photographically. No connection has as yet been established between them and the sequence of spectra described above.

A few peculiar stars like Nova Aurigæ remain, but their number is so small, that for the present each may be considered by itself.

The classification of the stars according to their spectra is so far-reaching that it should be applied to each of their other properties. For instance, of the variable stars it appears that all known Algol stars have spectra of the first type, while long period variables in general are of the third type, and have the hydrogen lines bright when near their maxima, as stated above. This property has led to the discovery of more than twenty objects of this class, and no exception has been found of a star having this spectrum whose light does not really vary. Of the variables of long period which have been discovered visually, the hydrogen lines have been photographed as bright in forty-one, the greater portion of the others being too faint or too red to be

studied with our present means. A few variable stars like U Hydræ, R Sculptoris, and B.D. + 62° 596 are of the fourth type. Their variation is small and their red color renders their visual observation uncertain. Variable stars of short period generally have spectra of the second type, but some like β Lyræ present special peculiarities.

The motion of the Sun in space, as derived from stars of each class of spectrum, is a problem of especial importance. The plan of the Henry Draper Memorial provides for the study of each of these and similar problems.

In general, it may be stated that with a few exceptions, all the stars may be arranged in a sequence, beginning with the planetary nebulæ, passing through the bright-line stars to the Orion stars, thence to the first type stars and by insensible changes to the second and third type stars. The evidence that the same plan governs the construction of all parts of the visible Universe is thus conclusive.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., August 5, 1893.

CONCERNING THE NATURE OF NOVA AURIGÆ'S SPECTRUM.*

W. W. CAMPBELL.

The earliest observations of the August, 1892, spectrum of Nova Aurigæ convinced me that it was nebular. There was not the slightest resemblance to any other known type: the continuous spectrum was extremely faint, as in the case of the planetary nebulæ; the spectrum consisted almost wholly of isolated bright lines; the three brightest lines had the relative positions and intensities of the three characteristic nebular lines; and a hasty examination of four well-known nebulæ resulted at once in finding eight other nebular lines which corresponded to eight of the prominent lines in the new star. Without tabulating the results of the comparison with nebular spectra, I stated in September and October that "The spectrum is that of a planetary nebula. . . . Nearly all these lines have been found either in the planetary nebula ≥6 or in the Orion nebula; the lines in Nova's spectrum, however, being displaced four or five tenth-meters towards the violet."

In a learned paper, "*Ueber den neuen Stern im Fuhrmann,*" just

* Read at the Congress of Astronomy and Astro-Physics, Chicago, 1893.

published, Professor Vogel expresses the opinion that the spectrum is not that of a nebula, and inclines to the view that the bright lines are chromospheric. In reviewing my observations Professor Vogel says (page 42):

"But as Huggins has pointed out, the brightest line in the star spectrum upon which the entire wave-length determination is based, is certainly (bestimmt) not the nebular line, since it is a group of lines, and not a single sharply defined line. It remains certain, therefore, that according to these observations there is very little basis for considering that the star spectrum is that of a nebula."

I must remark first that my wave-length determinations *do not depend upon the wave-length of the line at 500.* The wave-length of each line was determined entirely independently of that at 500, by reference to the artificial spectra of hydrogen, lead, magnesium, mercury, etc. Each line-determination stands upon its own merits. Further, I have always described the lines as abnormally broad,* and have observed that the appearance of the brightest line changes. On August 23, 1892, I measured the positions of two apparent maxima at wave-lengths 5005.9 and 5000.3. In September, October and November,† 1892, the maximum intensity was at the center of the band. In February and April, 1893, the band was broader and nearly of uniform intensity throughout. At no time, however, has there been any excuse for making an error of one tenth-meter in measuring the wave-length of the center of the band.

Since receiving Professor Vogel's paper, I have made a few more visual and long exposure photographic observations of nebular spectra, and without difficulty have found five other lines which also exist in the new star. The results for the nebulæ are given below, without discussion, simply for their bearing upon the character of the new star.

Orion Nebula.

Only one photograph of the spectrum of this nebula was obtained, in October, 1892. The slit was directed upon the region including and preceding the trapezium. The photographic field ended at wave-length 383. D_3 was observed visually.

D_3	Very faint.	4390	Bright.	4067	Bright.
5007	1st nebular line.	4363	"	4026	"
4958	2nd " "	4341	Hγ, very bright.	3969	H, very bright.
4862	Hβ, 3d nebular line	427	Very faint.	3889	α, bright.
4713	Bright.	424	" "	3868	Bright.
4661	"	4102	Hδ, Very bright.	3836	β, bright.
4473	Very bright.				

* See Astronomy and Astro-Physics, October, 1892, p. 718.
† *Ibid.*, February, 1893, p. 149.

This list of nineteen lines contains twelve not previously observed. Comparison with the photographic results obtained by Dr. and Mrs. Huggins reveals striking differences. My plate does not show the groups of fine lines obtained by them, and their plate shows none of the bright and very bright lines obtained by me except Hγ. Yet my photograph seems to refer to the same region of the nebula as their photograph of 1888. There are traces of several other lines, but their reality must be tested by another plate.

G. C. 4390, (Σ6).

The measures of D_3 were made visually in 1892. Of the others, those in the first two columns were made in 1892, and those in the last two in 1893. Several faint lines seen in the green have not been measured.

5877	5873	5877		D_3, faint.
5007	5007	5007	5007	1st nebular line.
4958	4958	4958	4958	2d " "
4862	4862	4862	4862	Hβ, 3d nebular line.
.....	.....	4744	4743	Faint.
472	4716	4714	4712	"
4687	4686	4687	4687	"
.....	.....	.....	4663	Very faint.
4634	4640	4635	4638	Faint.
.....	.....	.....	4610	Very faint.
.....	.....	460	4595	" "
.....	.....	.....	4574	Faint.
4472	4473	4473	4473	Very bright.
.....	4390	4390	4390	Faint.
4365	4364	4364	4364	Bright.
4341	4341	4341	4341	Hγ, very bright.
.....	4102	4102	4102	Hδ, " "
.....	.....	.....	4026	Very faint.
.....	.....	3969	3969	H, bright.
.....	.....	.....	3868	Bright.

So far as I know, twelve of these twenty lines are new.

N. G. C. 7027.

The results in the first column were obtained from a short-exposure photograph in 1892. Those in the last three columns were obtained visually in 1893.

.....	D_3	D_3	D_3	Very faint.
.....	.....	5752	5750	" "
.....	5412	5413	5412	Faint.
.....	533	.....	5413	Very faint.
5007	.....	.....	.....	1st nebular line.
4958	.....	.....	.....	2d " "
4862	.....	.....	.....	Hβ, 3d nebular line.
4741	4745	.....	.....	Bright.
4716	4716	.....	.....	Faint.
4688	4688	4688	.....	Very bright.
.....	4631	.....	.....	Faint.
4363	.....	.....	.....	Bright.
4341	.....	.....	.....	Hγ, very bright.
4102	.....	.....	.....	Hδ, " "

Seven of these lines appear to be new. That at 5751 coincides with the bright yellow line in the new star; that at 5412 with a prominent line in the Wolf-Rayet stars; and that at 532 is probably the coronal line 5317.

G. C. 4964.

The measures in the first column were made visually in 1892; those in the last two columns photographically in 1893.

532	.....	.....	Very faint.
.....	5007	5007	1st nebular line.
.....	4958	4958	2d " "
.....	4862	4862	Hβ, 3d nebular line.
.....	4744	4744	Faint.
.....	4715	4713	"
4684	4687	4688	Very bright.
.....	466	4663	Very faint.
.....	4638	4642	Faint.
.....	4473	4472	Very faint.
.....	4364	4364	Bright.
.....	4341	4341	Hγ, very bright.
.....	4102	4102	Hδ, very bright.
.....	.....	4067	Very faint.
.....	.....	4026	" "
.....	.....	3969	H, very bright.
.....	.....	3868	" "

Ten of these lines appear to be new.

G. C. 4373.

These results were obtained from a short-exposure photograph in May, 1893.

5007 1st nebular line	4363 Faint.	4026 Bright.
4958 2d " "	4341 Hγ, very bright.	3969 H, very bright.
4862 Hβ, 3d nebular line	4102 Hδ, " "	3888 α, bright.
4472 Bright.	4067 Bright.	3867 Bright.

Five of these lines appear to be new. The spectrum strongly resembles that of the Orion Nebula.

Comparison of Nova Aurigæ's Spectrum with the Nebular Spectra.

The results for the nebulæ are given in the first five columns of the following table. In the sixth column are the measured wavelengths of seventeen lines in the Nova's spectrum, and in the seventh column are their intensities. It must be explained that the intensities given above for the nebulæ are from the photographs, while those for the brightest lines in the Nova are visual and those for the faint lines in the photographic region are estimated from the photographs in terms of the brightness of the line 436. Estimates of brightness can be made only roughly

from my photographs, since for a given position of the slit, light of one given wave-length only will enter the slit properly, owing to the large chromatic aberration of the 36-inch lens.

I have omitted from my original list of lines those at (557) and at 5268, for the reason that they were too faint to permit an accurate determination of their positions. The former was visible in a small spectroscope with low dispersion, but was invisible in the large spectroscope. The wave-length assigned to it by me is a mere eye estimate, and it could easily be the line 554 observed by Professor Vogel in several planetary nebulæ. The line 5268 was visible in the large spectroscope with difficulty, and only one setting of the micrometer wire upon it was attempted. But Professor Vogel has also observed a similar line at 527 in G. C. 4373 and the Orion Nebula (*Scheiner's Spectralanalyse*, pp. 248, 250). I have not searched for lines at these places, since the wave-lengths in the case of the two Nova lines are not well enough fixed to make a successful search of any value.

Orion Nebula	G. C. 4390 Σ 6	N. G. C. 7027	G. C. 4964	G. C. 4373	Nova Aurigæ.	Intensity.
D_3	5876	D_3	.....	.....	.....	.....
.....	.....	5751	.....	.....	5750	1
.....	.....	5412	.....	.....	.....	.....
.....	.....	5313	532	.....	.....	.....
5007	5007	5007	5007	5007	5002	10
4958	4958	4958	4958	4958	4953	3
4862	4862	4862	4862	4862	4857	1
.....	4743	4743	4744	.....	.....	.....
4713	4714	4716	4714	.....	471	0.1
.....	4687	4688	4686	.....	4681	0.4
4661	4663	.. ...	4663	.....	.....	.....
.....	4637	4631	4640	.....	4630	0.7
.....	4610	.....	.....	.....	460	0.1
.....	4595	.....	.....	.....	.....	.....
.....	4574	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	451	0.1
4473	4473	.....	4472	4472	4466	0.1
4390	4390	.....	.....	.....	438	0.1
4363	4364	4363	4364	4363	4358	0 8
4341	4341	4341	4341	4341	4336	0.1
427	.....	.....	.....	.....	426	0.1
424	.....	.....	.....	.....	423	0.1
4102	4102	4102	4102	4102	4098	0.2
4067	.....	.....	4067	4067	.....	.....
4026	4026	.....	4026	4026	.....	.....
3969	3969	.....	3969	3969	396	Trace.
3889	.....	.....	.....	3888	.....	.....
3868	3868	.....	3868	3867	.....	.....
3836	.....	.....	.....	.....	.....	.....

I am not certain that any of these nebulæ contain a line near the wave-length 451; but the other sixteen Nova lines are matched perfectly in one or more of them, allowing for the fact

that the Nova lines were shifted about five tenth-meters (in August and September, 1892,) towards the violet. The Nova spectrum certainly differs no more from the nebular spectra than the nebular spectra differ from each other.

It can safely be assumed that the lines at 4857, 4336, 4098 and 396 are the well-known hydrogen lines Hβ, Hγ, Hδ and H. The strongest lines in the spectrum, at 5002 and 4953, then represent perfectly the positions and intensities of the well-known 1st and 2d nebular lines. There is no other type of spectrum in which these lines are known to exist. All the other well-determined Nova lines correspond perfectly to well-determined nebular lines. The presence of the chromosphere line 4472 and the four hydrogen lines must be considered as strengthening rather than weakening my argument, since they exist in the nebulæ and are important factors in the definition of a nebular spectrum.

Nearly all the lines in the February, 1892, spectrum of Nova corresponded to the prominent lines in the solar chromosphere, and *vice versa*. Aside from the hydrogen lines, that correspondence has now become a striking discordance.

In view of the broad and multiple character of the prominent lines in the February, 1892, spectrum we would naturally expect the present lines to be broad and complex. These characteristics of the lines in the early spectrum did not prevent us from arguing that they were chromospheric; why should the same characteristics of the present lines prevent us from arguing that they are nebular?

If the present lines are multiple, the problem only becomes more interesting and more hopeful of solution.

If the spectrum is *not conceded to be nebular*, I must ask what else we should expect to find in that spectrum *if it were* nebular.

Mount Hamilton, August 1, 1893.

ADDENDUM.

After forwarding the above to the Secretary for presentation to the Congress, I received and read with great interest the paper on this subject by Dr. and Mrs. Huggins, in the August, 1893, Astronomy and Astro-Physics. Their observations were confined to the three principal lines in the spectrum, and indeed almost wholly to the brightest one of the three. They write that as soon as they directed the spectroscope to the star, (Feb. 1, 1893), they saw at once, even with one prism, that the two principal bright bands which had been described as the "nebular lines" were in strong contrast with these, not single lines but

broad bright spaces, diffused at the ends and irregularly bright, which they suspected to be groups of bright lines.

These characteristics of the lines agree perfectly with those described by me one year ago, in my first article on the Nova, except that in addition I observed several changes in the appearance of the brightest line. At that time I wrote . . . "The difficulties in the way of deciding the question arise not from the faintness of the lines but from their great breadth. They are more diffuse than those of any of the planetary nebulæ which I have observed. With the grating the line λ 5002 is at least eight tenth-meters broad, with diffuse edges, and a brighter central region about four tenth-meters broad. On August 30 the line was suspected to be double, and the grating measures of that night refer to a point midway between the two condensations. On Sept. 7 the measures refer to a point of maximum brightness slightly less refrangible than the center of the line." See ASTRONOMY AND ASTRO-PHYSICS, Oct. 1892, p. 718.

As a result of further observations Dr. and Mrs. Huggins conclude that the bands at λ 501 and λ 496 consist of lines more or less bright upon a feebly luminous background, with possibly some absorption lines. Their work in the rest of the spectrum was confined to satisfying themselves, "by a direct comparison, that the line about F was really the hydrogen line in that region."

They wish to speak at present with great reserve concerning the character of the spectrum, since the observations are incomplete; but they "do not regard the circumstance that the two groups of lines above described fall near the positions of the two nebular lines as sufficient to show any connection between the present physical state of the Nova and that of a nebula of a class which gives these lines."

I can readily assent to that conclusion.

But in interpreting the spectrum of Nova we must not limit ourselves to our knowledge of those two bands or groups of lines. The rest of the spectrum must also be considered. Now Dr. and Mrs. Huggins, and several other observers, have found that the intensities and relative positions of the three most prominent lines or bands in this spectrum agree *perfectly*, within the limits of error, with those of the three most prominent nebular lines.* I have observed nineteen lines in the Nova, eighteen

* My recent observations of these three bands in Nova give for their wave-lengths, λ 5006.0, 4958.3, 4860.2. These wave-lengths have increased or decreased simultaneously since August, 1892.

of which may be said to correspond perfectly to lines in the nebulæ. Herr von Gothard has observed seven lines, six of which he believes to exist in the spectra of several nebulæ. Four of these six coincide with four lines in my list, and the other two are in the ultra-violet, quite beyond the limits of my photographs of the Nova spectrum. Now if only the brightest two of the twenty-one known lines were broad bands or groups of lines, and the other nineteen were narrow and well defined, a question might possibly be raised as to the origin of the two groups. But such is not the case.

The "line about F" is seen with the large telescope to be a band, apparently identical in form with those at the positions of the two chief nebular lines; and likewise, with certainty, those at λ 463 and λ 436. Whether the fifteen fainter lines and the one at λ 575 are also very broad, it is impossible now to say; but in all probability they are. If any *one* of these bands consists of a group of lines, it is very probable that they *all* do; and it would not, then, be a question of identifying each line in each group with some chemical element, but of observing the *arrangement of the lines in the groups*, in the hope of solving the problem of whether the Nova is *one* nebula, or a system of *several* nebulæ.

The lines in the February, 1892, spectrum occupied in general the positions of the solar chromosphere lines; those lines were broad, and many of them were multiple; but those facts did not prevent us from arguing that the spectrum was chromospheric.

The lines in the present spectrum do not occupy the positions of the prominent lines in the February, 1892, spectrum, nor the positions of lines in the solar chromosphere, nor the positions of the lines in any of the bright-line stars; they do occupy the positions of the lines in the nebulæ; the spectrum resembles nebular spectra as closely as well known nebular spectra resemble each other: therefore the spectrum is nebular, and the fact that the lines have remained broad, or may have remained multiple, does not militate against the theory.

Mount Hamilton, Aug. 11, 1893.

PRELIMINARY NOTE ON THE CORONA* OF APRIL 16, 1893.†

J. M. SCHAEBERLE.

The accompanying photographs‡ of the inner corona were made from two of a series of eight negatives taken with a forty-foot telescope on 18×22 inch Seed plates, Sensitometer No. 26. The duration of exposures and the approximate times after the beginning of totality are as follows:—

No. of Negative.	Exposure Time.	Approximate times after beginning of Totality.
	s	s
1	0.25±	2
	s	s
2	2.00	16-18
3	4.00	32-36
4	8.00	50-58
5	16.00	72-88
6	32.00	102-134
7	24 ±	148-172
8	0.25±	186 ±

In the 32ˢ exposure nearly the whole area of the 18×22 plate is covered by the corona. The corona was seen projected on the screen inside of the forty-foot telescope several minutes before 2d contact, and although the last exposure was taken nearly a quarter of a minute after totality the inner corona and the prominences are conspicuous features of this plate, except where the Sun's limb has burnt out the detail.

As bearing directly upon the theory of the corona, the photographs taken with five different instruments at the same station show:

1st. That apparently the matter composing the prominences and protuberances visible during this eclipse was in orbital motion. In the prominences the matter is distributed with varying density along elliptical arcs symmetrical with reference to the Sun; in many cases these arcs seem to be partially discontinuous; they vary all the way from a normal line to a nearly tangential curve and attain a maximum altitude of about 80,000 miles.

The protuberances visible during this eclipse are shown to be made up of a large number of bright elliptical streams of matter

* Observed at Mina Bronces, Chile.
$\lambda = 76°\ 19'$, $\beta = -28°\ 27.'$ Height = 6600 feet.

† Read at the Congress of Astronomy and Astro-Physics, Chicago, August, 1893.

‡ The positive copies from the original negatives were made by Mr. A. L. Colton of this Observatory.

which intersect each other, in projection, at all angles. These streams are so numerous that on the smaller scale photographs this network of lines has the appearance of a continuous surface.

In this note I consider all photographically visible matter exterior to the Sun's surface as forming part of the corona, and for convenience of illustration the higher and conspicuously individual portion of any protuberance is called a prominence; the former during this eclipse attained a mean height of about 20,000 miles while the latter as conspicuous structures rose to a maximum height of four times this amount.

2d. All the remaining visible matter forming the Sun's corona is apparently of a uniform degree of composition and much less dense than the prominences and protuberances, but like them the matter is arranged in the form of (continuous) curved streams of various heights and each returning stream of the inner corona is plainly visible as a portion of an ellipse whose major axis passes through the Sun's center, indicating that the matter forming these streams was ejected from the Sun and is subject to the action of the Sun's gravity. The symmetrical form of these complete arcs (varying again, all the way from a normal line to a nearly tangential stream) indicates that this rare matter suffers practically no resistance to motion due to an atmosphere of the Sun. Structures again which on the smaller plates appear to follow no law are, with the aid of the larger plates shown to be due to the superposition of these elliptical streams. That these arcs are not due to halation caused by the presence of bright prominences follows from the fact that the eccentricity varies as above stated and from the further fact that no visible change of form took place with reference to the true place of the Sun during the Moon's transit. These visible returning streams are much the most numerous on either side of the Sun's equator and attain a height of 200,000 miles or more.

3d. The outer corona is mainly caused by more nearly radial streams of matter wholly similar in appearance to the curved returning streams of the inner corona. The various trumpet-shape outlines so plainly visible on the smaller wide-angle plates are seen to be due to the superposition of individual streams which in many cases can be traced from the Moon's outline on the larger plates to a distance of several solar diameters on the smaller negatives.

In no case have I found the actual structure to be concave towards the Sun's center, and there are only a few cases of very large streamers having apparently greatly inclined initial direc-

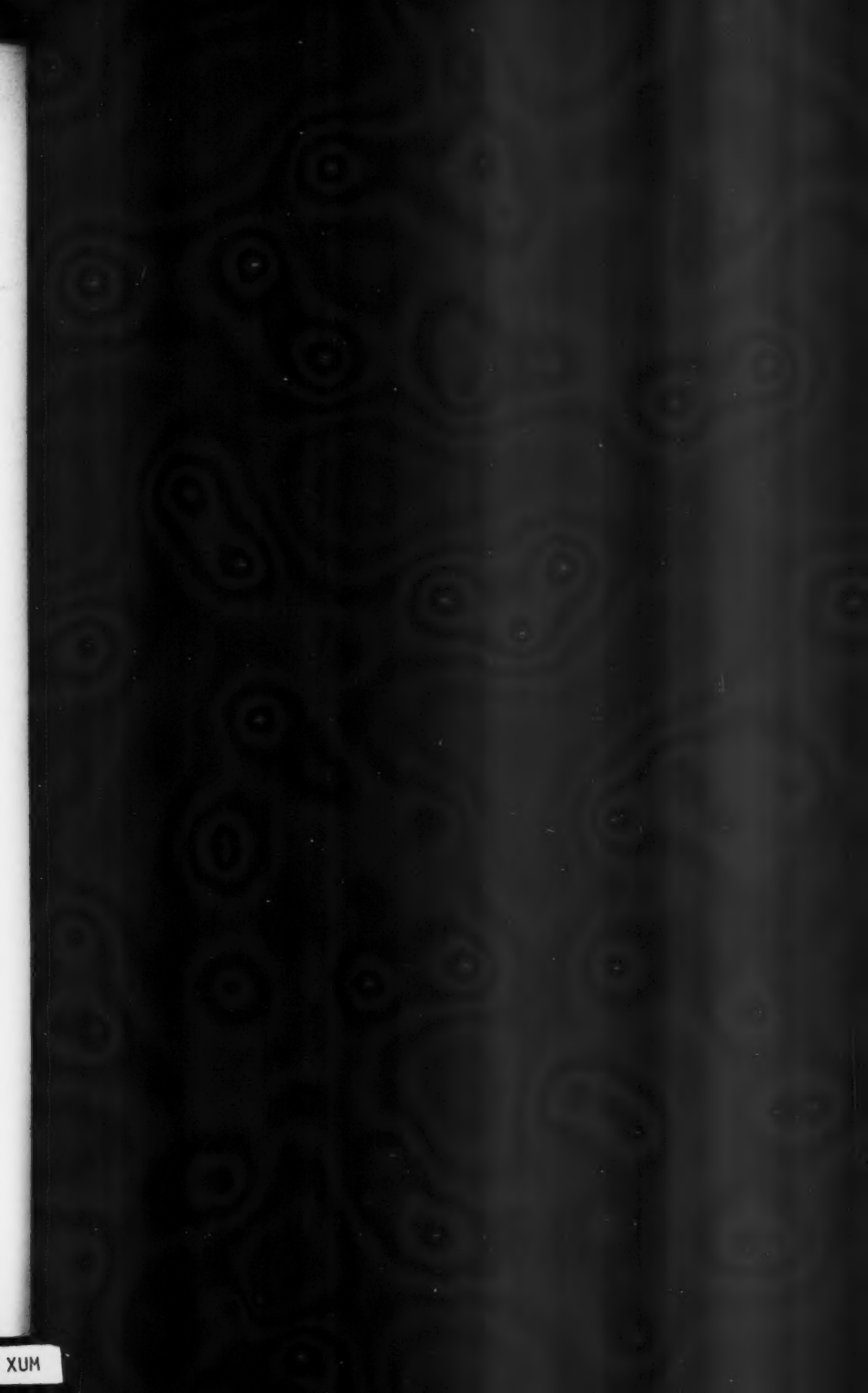
tions of motion corresponding to very great velocities, the points of eruption being on or near the Sun's limb. The general form of the outer corona is in general agreement with the prediction for a nearly maximum inclination of the Sun's north pole to the line of sight, although the axis of the inner corona cannot be accurately determined owing to the condensed state of the projections in the polar regions. Marked extensions (nearly radial) projecting far beyond the usual elliptical outline are found on various quadrants, especially so in the north polar regions. I wish to call particular attention to a curious structure near the middle of the 4th quadrant; the head of this comet-like object is about four-fifths of a solar diameter from the Sun's surface; it is visible on all my negatives of the outer corona.

On the Dallmeyer negatives of the outer corona the Zodiacal Light shows faintly to a distance of about eight solar diameters from the Sun.

In my "Mechanical Theory" certain results are deduced for a typical corona produced by streamers uniformly distributed in the spot-zones. Now it is evident that this ideal or perfect form will be the exceptional case, and for the same reason that the visible solar disturbances in the two spot-zones differ not only from each other, but the study of the Sun's visible surface tells us that the eruptions are not as a rule distributed with exact uniformity in longitude.

The form resulting from an irregular distribution of the streamers can be constructed provided the longitudes of the various points of eruption and the distance from the origin are known. As the observer will in general have a less latitude than a given stream it follows that the normally ejected outgoing matter between the Earth and Sun will in projection curve away from the equator on the west side of the Sun, and on the east side the curvature will be towards the Sun's equator for the reason that the outgoing streams in both the northern and southern hemispheres will be on the east side of the normals. Just the opposite condition of things will exist for the outgoing streams* on the farther side of the Sun. (See L. O. Report on the eclipse of Dec. 1889, Plate VIII). For the incoming streams the inclination is reversed. The resulting form of the corona in any particular quadrant will depend upon the relative amount of ejected matter in the nearer and farther hemispheres of the Sun's surroundings, projected in that quadrant. When the observer is exactly in the

* A distant portion of a normally ejected stream may in projection actually coincide with a tangent to the Sun's disk.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Owing to delay in the reproduction of the plates to accompany Professor Schaeberle's article, it will be necessary to reserve the long-exposure photograph of the corona for publication in the next number of ASTRONOMY AND ASTRO-PHYSICS. The photograph reproduced herewith was made with a short exposure, and consequently shows only the prominences and the brighter portions of the inner corona.

PLATE XXXI

N

Sun's Equator.

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THE CORONA OF AP

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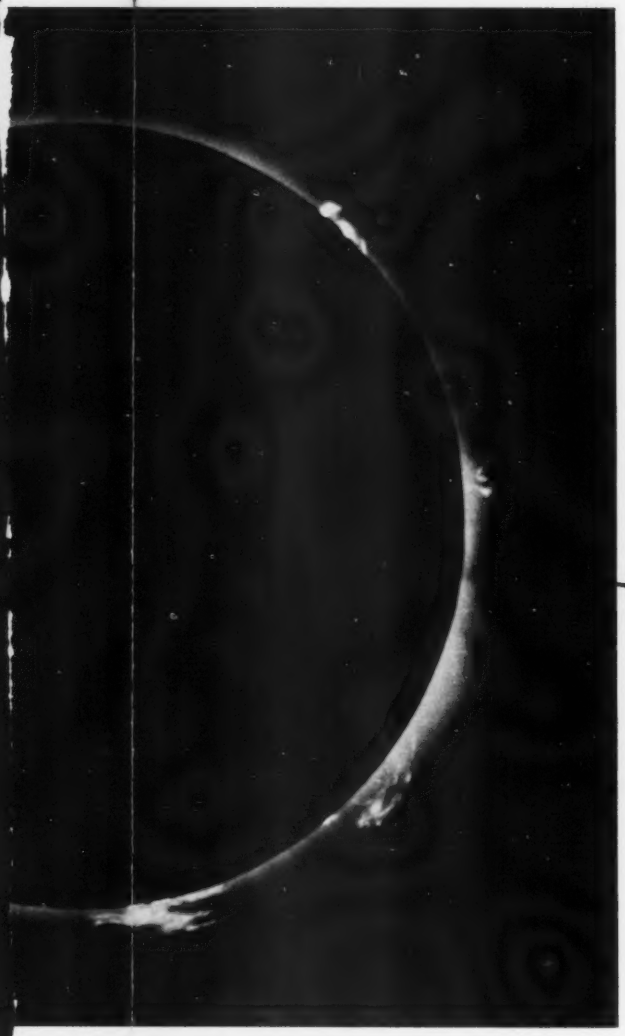
PLATE XXXIX.

N



W

Sun's Equator.

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plane of motion the streams will coincide with normals in projection.

A streamer is evidently made up of a number of nearly parallel streams of matter having presumably many streams with divergent directions of motion. At great distances from the origin such a streamer projected nearly in the direction of the Sun will during an eclipse appear to radiate from a considerable arc of the Moon's limb, the amount and direction of the inclination to the normal being governed by the conditions above indicated.

A considerable interval between two such sets of streamers would result in "gaps" or "rifts" in the corona; when such eruptions actually take place on the Sun's limb those streamers which have greatly inclined initial directions of motion may evidently also become visible.

Referring now to the coronal photographs of the April eclipse and numbering the quadrants 1, 2, 3, 4, in the order NE, ES, SW, WN, referred to th projection of the Sun's axis, the observed forms are explained as follows:

In the first quadrant streams both on this and the farther side of the Sun are seen in rojection with a preponderance of the former. The same distribution will account for the forms in the second quadrant. In the third quadrant the streams of the farther hemisphere are almost completely eclipsed by those of the nearer hemisphere. Finally in the fi t half of the fourth quadrant only the streams of the nearer hemisphere are seen while the second, or polar half of the same quadrant has practically the same arrangement as the first half of the first quadrant. The structure in the equatorial regions (giving the appearance of two opposite magnetic poles on the Sun's equator) is in agreement with the theory that the streams of matter are ejected from the spot-zones and subject to gravitational influences. During this eclipse several powerful eruptions were in action near the Sun's west limb.

A discussion of all the material available will be embodied in a report on this eclipse.

Lick Observatory, Aug. 10, 1893.

THE WAVE-LENGTHS OF THE TWO BRIGHTEST LINES IN THE SPECTRUM OF THE NEBULÆ.*

JAMES E. KEELER.

In No. 11, Vol. II, of the Publications of the Astronomical Society of the Pacific, I published a preliminary account of spectro-

* Read at the Congress of Astronomy and Astro-Physics, Chicago, August 1893.

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scopic observations of Nebulæ with the 36-inch equatorial of the Lick Observatory, containing among other things, measurements of the positions of the brightest nebular lines, and a table giving numerical values for the motion of various planetary nebulæ in the line of sight. These observations were afterwards considerably extended, and the results embodied in a memoir which will be published in due time by the Lick Observatory.

As the publication of this memoir has, however, been delayed, and as my final values for the positions of the principal nebular lines, although they have been quoted from my manuscript by a number of writers, have not appeared in print in a suitable form for reference, it seems to me desirable to give the results for these lines in advance, leaving the individual measures and a description of the methods employed, together with other observations of stars and nebulæ, to the memoir above referred to. I wish also to point out the cause of slight differences in the numerical results given in my previous papers.

The instruments employed in these observations were the 36-inch equatorial and the large spectroscope of the Lick Observatory. The spectroscope was furnished with a Rowland grating, and the nebular lines were observed in the third and fourth spectra. In the fourth spectrum the dispersion was nearly equal to that of twenty-four 60° flint prisms, and the effective aperture of the spectroscope was 1.08 inch. The employment of this dispersion, which would be considered large even in solar spectroscopy, was possible only by virtue of the extreme homogeneity of the nebular radiations, their spectral lines appearing as strictly monochromatic images of the slit. The positions of the lines were micrometrically determined with reference to known metallic lines.

In my preliminary paper the normal position of the chief nebular line was taken to be λ 5005.68 on Angström's scale, a value which was the average of the positions of this line in all the nebulæ I had observed up to that time. By "normal position" is meant the position of the line in the spectrum of a nebula at rest relatively to the observer. As nearly all these nebulæ were in that quarter of the heavens which the solar system was approaching at the time of observation, the wave-length given above is too small by an uncertain amount. The third nebular line (due to hydrogen) not having been observed, and the origin of the principal line being unknown, this result was the best that could be obtained under the circumstances. The position of the second line was λ 4957.7 (Angström), and as it was referred to that of the first, it was subject to the same uncertainty.

In October, 1890, I succeeded in obtaining comparisons of the third line in the spectrum of the Orion nebula with terrestrial hydrogen, and found that the nebula was receding from the solar system at the rate of 10.7 ± 1.0 miles per second. The position of the chief nebular line, corrected for the displacement caused by this motion, was λ 5005.93 on Angström's scale, and this result is affected only by errors of observation and of the wave-lengths of the lines chosen as standards of reference. The results were published in the Proceedings of the Royal Society, Vol. 49, p. 399.

Reduced to Rowland's scale, the wave-length of the chief line, according to these observations, is λ 5006.71; corrected for errors, subsequently determined, in the wave-lengths of the reference lines it is λ 5007.01.

Later in 1890, and in 1891, I succeeded in obtaining accurate comparisons of terrestrial hydrogen with the third line in the nebula G. C. 4390, which is situated in a part of the heavens nearly opposite to the nebula of Orion. The latter nebula was also frequently re-observed, and these independent results were in complete accordance. Many measures were also obtained of the second nebular line, both with reference to the principal line and to standard metallic lines.

Reduction of all these observations brought out clearly the rather remarkable fact that the measures of these faint nebular lines were much more accurate than were the positions of the metallic lines which I had used as standards, and which I had taken from the best tables then available. Micrometric measures were made with the Lick Observatory spectroscope of such lines as were close enough for this method, and the individual results for each nebular line were thereby brought into excellent agreement, but the instrument was not adapted to the precise measurement of large intervals. Finally I obtained from Professor Rowland his then unpublished measures of standard metallic lines, and all the work was then found to be in perfect harmony. The results of all the observations, so far as they relate to the positions of the nebular lines, are as follows:

Normal position of the chief nebular line on Rowland's scale..... λ 5007.05 $\pm$ .03

Normal position of the second nebular line on Rowland's scale..... λ 4959.02 $\pm$ .04

These are the values given in Professor Rowland's New Table of Standard Wave-Lengths, in ASTRONOMY AND ASTRO-PHYSICS, April, 1893.

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The greater part of the probable error is due to the comparisons with the third line, which could not be observed with the same accuracy as the first. The motion of the Orion nebula, referred to the Sun, from all the observations, is $+ 11.0 \pm 0.8$ miles per second, and the wave-length of the chief line in this nebula, corrected for orbital motion of the Earth, is $5007.34 \pm .013$.

These results show, (for the first time conclusively), that the two principal nebular lines are not represented by absorption lines inthe solar spectrum.

It is also evident that the use of Angström's scale in Astronomical spectroscopy must be abandoned, not so much on account of its systematic deviation from the true normal scale, as on account of the accidental errors with which it is affected, and which are sometimes of a magnitude that cannot be neglected in the present state of astro-physical research.

CONTRIBUTIONS ON THE SUBJECT OF SOLAR PHYSICS.*

E. R. VON OPPOLZER.

In solar physics, few things would be of greater value than accurate information regarding the constitution, the cause, the heliographic distribution, and the motion of sun-spots.

These spots place us in a position to determine not only the rotation-period and the rotation-axis but also the peculiar rotation-law of the sun.

With reference to the constitution of sun-spots, our notions are already clear. After the experiments of Young and Dunér, there can be no doubt that sun-spots are gaseous and of the same chemical structure as the atmosphere in which they float. From Kirchhoff's law, also, it follows that these spots are simply cooled regions in the solar atmosphere. The existence of storms in the neighborhood of spots has been shown by the spectroscope; and we have, indeed, no ground left for considering spots anything but meteorological phenomena. The explanation of these phenomena must be clearly grasped in terms of meteorology before we pass to other explanations. To look in the direction of electrical effects, as Schuster has lately done, appears especially promising. It is simply a question of solar meteorology. But here one is treading on dangerous ground. For as regards the

* Read at the Congress of Astronomy and Astro-Physics, Chicago, August, 1893.

meteorology of even our own atmosphere, we are not agreed as to the fundamental principles, as witness the discussion between the adherents on the one hand, of the "Convection Theory," on the other of the "Dynamical Theory." This, in spite of the tremendous accumulation of observations.

The science, however, has been materially advanced by the recent application of the kinetic theory of gases, and the mechanical theory of heat to our atmosphere, as well as by the establishment of mountain stations at numerous points on the Earth.

In what follows, we shall derive the condition of equilibrium in the solar atmosphere from the laws of gases and the dynamical theory of heat. To be sure it may be objected that the application of these theories to the solar surface is not admissible. However recent experiments and considerations lead us to think that in the sunspot-layer and the immediately overlying regions, we have to deal with a gas which is in a state of extreme tenuity, a state of rarefaction, indeed, far exceeding that of the Geissler tube. In fact, one might say that he has here to do with a "perfect gas," and that, therefore, the application of the above mentioned theories is more than justified. From the condition of equilibrium, we may then infer certain effects and predict certain motions.

Let us begin with an ideal surface N_0, in which the pressure is p_0 and the absolute temperature T_0. Imagine now a unit of mass to be carried to this surface N_0, from any surface N in which the pressure is p and the temperature T. Let h be the distance from the surface N to N_0. The pressure, as well as the temperature increases with the depth. In case no heat is added to or taken away from the mass-unit, it will undergo an adiabatic compression. The heating thus produced could easily be computed if only the distance h, the variation of pressure and temperature with depth, and the nature of the gas were known.

Whatever be the constitution of the atmosphere, the decrease in pressure, dp, corresponding to an increment in height, dh, obeys the law

$$\frac{dp}{p} = -\frac{\gamma}{RT}\,dh$$

where $\gamma = g'/g$, the ratio of gravity on solar surface to gravity on the earth.

R = constant involved in the law of Guy Lussac and Mariotte, *viz.*: $pv = RT$.

T is an unknown function of h; otherwise one might integrate the equation and obtain immediately the law according to which

the pressure diminishes with the height. We are at liberty, however, to *assume* certain conditions. The mass which we brought to surface N_0 was heated adiabatically; but suppose that the temperature of the surrounding atmosphere increased with the depth faster than this adiabatic heating from compression. Then the mass would arrive at surface N_0 with a lower temperature than prevailed in surrounding regions. An upward motion in such an atmosphere would be accompanied by cooling of the mass moved. Such an atmosphere would be in unstable equilibrium. If, however, the temperature increases more slowly than the adiabatic heating, then we should expect a warming of the mass in the lower layers. The atmosphere would then remain in stable equilibrium. There is still an intermediate state possible, in which the transportation of a mass in a vertical direction is unaccompanied by any change in temperature. In this case a mass at the altitude h, where the temperature is T, by transport to a lower surface N_0, where the temperature is T_0, suffers a change of temperature, ΔT, such that

$$\Delta T = T_0 - T$$

so that the mass arrives at surface N_0 with temperature T_0. This state might be called the "indifferent" state, or state of neutral equilibrium. From Poisson's law, *viz*:

$$\frac{dT}{T} = \frac{k-1}{k}\,\frac{dp}{p}$$

and the above equation, we obtain the diminution of temperature due to an elevation of unit distance:

$$\frac{dT}{dh} = -\frac{\gamma}{R}\cdot\frac{k-1}{k} = \theta = \text{constant.}$$

where, $k = \frac{C_p}{C_v}$ the ratio of the specific heats.

Assuming that the solar atmosphere is made up of hydrogen, the diminution of temperature per second [$1'' = 720860$ in.] is

$$\theta = 13740°$$

At a distance of one second above the photosphere, we have therefore, a prevailing temperature 14000° lower than on the surface of the photosphere.

Now the observations of Lockyer and Respighi show that a hydrogen atmosphere surrounds the Sun to the height of 420″, which would indicate a temperature at the surface of the photosphere of no less than 5,600,000°. On the contrary, the latest experiments, touching Stefan's law of radiation and Langley's solar constant, indicate solar temperatures, even allowing for absorption, of between 20,000° and 100,000°. It would appear, there-

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fore, that the *actual* changes of temperature θ occur more slowly than they would in the "indifferent" state, *i. e.*, in the state of neutral equlibrium. And, from what has been said before, we conclude that the solar atmosphere is in a condition of extremely stable equilibrium, so that any motion downwards in a vertical direction is accompanied by heating of the mass moved. If we take the temperature of the Sun as lying between the limits mentioned above, we are driven to admit, even in the most unfavorable case, that a current in passing from an altitude of 1″ to the photosphere, would be heated at least 6,000°. The cooling of the "spot-matter" could hardly, therefore, take place in the upper and cooler regions.

If we inquire what causes are effective in producing a local cooling of the atmosphere, two present themselves. The cooling may be due either to adiabatic expansion which is brought about, it may be by an ascending current, it may be by a vortex, or to some especially favored local radiation into space. To decide between these alternatives, we must refer to a very characteristic phenomenon of spots. The almost constant reversal of lines in the spot-spectrum shows (since these lines belong to the upper layers of the atmosphere) that the cool "spot-matter" is overlaid with a hotter layer. That this is not due to faculæ or prominences is shown by the observations of Hale, who finds that "the bright H and K lines seem to *invariably* extend *entirely* across *every* sun-spot. Both lines are doubly reversed in the faculæ which probably completely surrounded every spot. In the umbra, the reversals are narrower, and *the dark central line is usually absent.*"

For spots this appearance is characteristic. Hale explains it as follows: "The single reversals in the umbra, however, probably take their rise in the chromosphere, which presumably overlies the cooler regions of the spot."

The thermal observations of Langley and Frost indicate that the spots radiate more heat and less light than the limb of the Sun.

Since, however, Kirchhoff's law demands that the material of the spots be cool, we can only reconcile these two results by assuming that an abnormally hot layer overlies the spot material, so that the total heat-radiation of this layer and the spot exceeds that of the limb. Frost found spots from which the radiation even exceeded that of the surrounding photosphere. The spots lie sunken in the photosphere, which, as is well known, consists of products of condensation and has therefore a *dust-like* constitution.

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Over the spots the products of condensation are wanting; and this again is possible only on the assumption that there is an overlying hot layer which has vaporized the photospheric clouds. Since the light of the photosphere is emitted by the latter, the region over the spot would present the appearance of a depression.

All these phenomena emphasize the view that *over the spot region lies an abnormally hot layer, and that spots are places of extremer alternations of temperature.*

Such a characteristic property as this could hardly be ascribed to an ascending current or to a vortex, aside from the fact that one could hardly look for the same cause to produce spots, faculæ and prominences: for the appearance and heliographic distribution of the last two are very different from those of the spots. The inner portions of a spot present a picture of almost absolute quiet. The single remaining cause of cooling is, therefore, locally increased radiation into space. On this assumption, every objection disappears and the facts of observation are completely explained.

Not only from spectroscopic and thermal observations but also from theoretical considerations, it appears that some light from very great depths of the photosphere makes its way through the upper layers of the photosphere itself. The photosphere must exercise upon itself a tremendous absorptive effect since the thin outer layer [*Dunsthülle*] is a powerful protection against radiation from the depths of the photospheric layer.

Radiation from this layer would be very much favored by clearness and transparency in the upper layers of the photosphere; this in turn, would be the state of affairs when the upper layers were vaporized, and this, in turn again, when an abnormally high temperature prevailed. In short, abnormal heat in the upper layers of the photosphere favors radiation from the lower layers. In these lower, deeper parts is situated the cool "spot-material," while in the upper parts we have a condition of abnormally high temperature. *The phenomena demand, therefore, that we consider sun-spots as produced by extraordinary radiation from the underlying, deeper portions of the photosphere.*

The question now presents itself, whence come these hot layers overlying the "spot material"? Certainly not from regions still deeper, for this would bring about immediate destruction of the spot. Perhaps they are produced by hot winds from still hotter portions of the Sun's surface—possibly from faculæ. Against this view, however, stands the deep-seated position of the spot, and,

indeed, its entire structure which points to a more central origin. For the source of the heat we can only look, therefore, to the higher regions. We have already indicated how this might happen, descending currents of the atmosphere being accompanied by considerable evolution of heat. But why should this descending motion not penetrate the "spot-material? In answer, it must be remembered that this descending gas heats itself as it falls, and, by this very operation, exerts upon itself a buoyant effect which finally destroys the downward motion.

It is then to vertical "gradients" that we must look for the cause of these vertical motions. It can be shown that a vertical displacement from an elevation of over 4″ could not take place, since this would be accompanied by a variation of pressure amounting to more than fifty per cent of the whole pressure involved.

We arrive then at the conclusion that spots are produced INDIRECTLY *through a sinking down of masses upon the photosphere, and* DIRECTLY *through extraordinary radiation brought about by transparency of the overlying region.*

In our atmosphere, there occurs a similar phenomenon, first explained by Hann.

Regions of high pressure in our latitude are, in winter, regions of great cold on the surface of the Earth. The Earth is then covered with dense clouds. But observations at high mountain stations tell us this cold extends to a comparatively small height, and that above the cold region the air is exceptionally clear and transparent, and that the temperature is abnormally high. The cold layer on the Earth is overlaid by a warm layer. It can be shown also that the air over such regions is falling; and this explains the clearness and high temperature. This unusual transparency favors radiation into space and thus arises the cooling, and the clouds consequent upon this cooling.

Spörer has shown that currents, in the neighborhood of a spot diverge [*divergiren*] which would seem to indicate that spots are regions of high pressure. Spörer has also pointed out that places from which currents arise ("diverge"), are places at which, later, spots appear; so that I feel justified in considering spots as localities of high pressure; and, so far as their cause and structure are concerned, they are analogous to cold spots on the Earth's surface, determined by a high barometer in winter time. These regions would appear to an observer, outside the Earth's atmosphere, as deep, dark spots in a bright sea of cloud. These dark spots would allow one to get a glimpse of the Earth's surface now and then, provided the surface clouds were not too thick.

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On this theory of the appearance and disappearance of sunspots, there is, it must be confessed, ample room for the imagination to play.

At least, adjoining layers of widely different temperatures furnishes opportunity for great and sudden changes in the structure of the spot. The cooled masses are to be considered rather as a secondary phenomenon intimately connected with the descending currents, and related to them somewhat as a shadow is to the shadow-producing body. Old spots disappear with the horizontal displacement of the descending current, and thus make way for new ones. The material of which the spot is composed does not move but simply the current which produces the spot. To discuss the formation of groups of spots would require a more accurate knowledge of the dynamical processes which are going on in regions of high pressure. Since terrestrial meteorology cannot yet furnish us this information; we must forego any discussion of these details.

The reference of sunspots to descending currents sheds some light on their distribution in latitude. Considering suns-pots as regions of descending currents and remembering that, corresponding to these, there must be elsewhere regions of ascending currents, we are led, in view of the fact that the spots group themselves in zones parallel to the equator, to place these ascending currents in the polar regions. This view seems the more probable since the spot-belt sometimes reaches all the way to the equator, while at the same time increased activity appears in the higher latitudes, as indeed, is always the case at time of minimum. Polar regions, then, in the solar atmosphere, correspond to equatorial regions in the terrestrial atmosphere, in that each are places of ascending currents. The Sun thus has two great cyclones, one about each pole. Now consider these arising currents to vary in intensity, alternately increasing and diminishing, and you have the cause of the peculiar law of heliographic distribution discovered by Carrington and Spörer. Imagine an increase in the ascending current at the poles in the time of minimum; the consequence would be that the matter would sink, and spots form, in higher latitudes. With constantly increasing intensity of this current, the lower latitudes would be overstrewn with spots, and a spot-maximum would be the consequence. Let this polar up-rush diminish; the spots disappear from the higher latitudes and only the minimum number of spots remains in the neighborhood of the equator. The current again increases and we have a repetition of these phenomena.

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These two polar cyclones bring about a peculiar rotation law in different solar latitudes, a rotation law which must, of course, coincide with that of the solar atmosphere. A mathematical discussion of this atmospheric circulation is, at present, impossible. The facts, however, point to a general up-rush in the neighborhood of the poles; for the polar region is the zone of calm for the Sun. The appearance of the corona has led Bigelow to similar results. According to Trouvelot, the chromosphere during a minimum, that is at the beginning of a polar uprush, shows a mountainous outline, has a piled-up appearance; while during the year preceding a minimum there is, in all latitudes, a comparatively widespread calm.

On this theory of spots, the problems of the rotation of the Sun, the frequency of spots, and their distribution in latitude are all reduced to one, *viz.*, to the problem of a periodic uprush in the polar regions. The careful study of these three problems demands that we refer them to a common cause. The intimate relation between frequency and heliographic distribution is well known. The rotation-law as well appears to depend upon the frequency. Observations of spots can give us, during a single spot-period only a crude idea of any change in the law of rotation. But great things are to be expected from observations by the method of Dunér. To this method, astounding in its accuracy, we must look for a final solution of the problem of solar rotation. In solar physics there is no question of higher importance. Unfortunately Dunér's observations cover a period of three years, and these at a time of extreme inactivity.

ASRTO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS, should be addressed to George E. Hale, Kenwood Observatory of the University of Chicago, Chicago, U. S. A. Authors of papers are requested to refer to last page for information in regard to illustrations, reprint copies, etc.

The Congress on Mathematics, Astronomy and Astro-Physics.

The Congress on Mathematics, Astronomy and Astro-Physics was opened in the Art Institute, Chicago, on Monday, August 21, 1893, with addresses by Professor George W. Hough, Chairman of the Local Committee, and Professor Dr. Felix Klein, Official Delegate of the German Government. On motion of Professor E. H. Moore the Congress divided into two sections, one of Mathematics and the other of Astronomy and Astro-Physics.

In the Section of Mathematics the following program was carried out:

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TUESDAY, AUGUST 22, 9:30 A. M.

PAPERS—

Invariantentheorie, by Professor David Hilbert, University of Koenigsberg, Germany.

Ganzzahlige Gleichungen, by Professor Heinrich Weber, University of Goettingen, Germany.

Kronecker's arithmetisch-algebraische Tendenzen, by Professor Eugen Netto, University of Giessen, Germany.

Ueber die Reduction der binären quadratischen Formen, by Professor A. Hurwitz, of the Polytechnic Institute, Zurich, Switzerland.

On Fifth-Power Numbers, whose Sum is a Fifth-Power, by Artemas Martin, LL. D., of the U. S. Coast and Geodetic Survey.

LECTURES—

On the Definitions of the Trigonometric Functions, by Professor Alexander Macfarlane, of the University of Texas.

Complexe Zahlen, by Professor E. Study, University of Marburg, Germany.

Concerning Matrices and Multiple Algebra; by Professor Henry Taber of Clark University.

On the Algebraic Solution of Equations, by Professor A. M. Sawin, Evansville, Wis.

TUESDAY, AUGUST 22, 3 P. M.

Visit to the German University Exhibit at the Columbian Exposition.

WEDNESDAY, AUGUST 23, 9:30 A. M.

PAPERS—

Zahlentheorie und Geometrie, by Dr. H Minkowski, University of Bonn, Germany.

Geltungsbereich der Taylorschen Reihe, by Professor A. Pringsheim, University of Munich, Germany.

On Interpolation Formulæ and their Relation to Infinite Series, by Professor W. H. Echols, of the University of Virginia.

Résumé de quelques résultats relatifs à la théorie des systèmes récurrentes de fonctions, by Professor S. Pincherle, of the University of Bologna, Italy.

Singuläre Puncte einer algebraischen Curve, by Professor Max Noether, University of Erlangen, Germany.

Sur une intégrale définie qui représente la fonction $\zeta(s)$ de Riemann, by Professor M. Lerch, Prague, Bohemia.

LECTURES—

Modern Graphical Developments, by President H. T. Eddy, Rose Polytechnic Institute.

Some Salient Points in the History of Noneuclidean and Hyper-Spaces, by Professor George Bruce Halsted, of the University of Texas.

The Principles of the Elliptic and Hyperbolic Analysis, by Professor Alexander Macfarlane, of the University of Texas.

WEDNESDAY, AUGUST 23, 3 P. M.

Visit to the German University Exhibit.

THURSDAY, AUGUST 24, 9:30 A. M.

PAPERS—

Sur quelques propositions fondamentales de la théorie des fonctions elliptiques, by Professor Charles Hermite, Member of the Institute, Paris, France.

A Formulary for an Introduction to Elliptic Functions, by Professor Irving Stringham, Dean of the University of California.

Ueber die Transformation der hyperelliptischen Functionen, by Professor Martin Krause, Dresden Polytechnic, Germany.

Allgemeine Theorie der linearen Differentialgleichungen, by Dr. L. Heffter, University of Giessen, Germany.

Lineare Differentialgleichungen in der Astronomie, by Dr. Heinrich Burkhardt, University of Göttingen, Germany.

Automorphe Functionen und Zahlentheorie, by Dr. Robert Fricke, University of Göttingen, Germany.

LECTURES—

On Weierstrass' Systems of Abelian Integrals of the First and Second Kinds, by Professor Oskar Bolza, of the University of Chicago.

Spherical Trigonometry, by Professor E. Study, University of Marburg, Germany.

FRIDAY, AUGUST 25, 9:30 A. M.

PAPERS—

A Construction of Galois' Group of 660 Elements, by Professor Joseph de Perott, of Clark University.

Concerning the Formation of Groups, by Professor F. N. Cole, of the University of Michigan.

Krystallographie und Gruppentheorie, by Professor Arthur Schoenflies, University of Göttingen, Germany.

Die continuirlichen Gruppen der Ebene, by Professor Franz Meyer, Clausthal School of Mines, Germany.

Sur l'équation des lignes géodesiques, by Professor Edouard Weyr, of the Polytechnic Institute, Prague, Bohemia.

Einige Sätze vom Schwerpunkt, by Professor V. Schlegel, Hagen, Germany.

LECTURES—

On a Quaternary Group of 2520 Linear Substitutions, by Professor Heinrich Maschke, of the University of Chicago.

A Doubly-infinite System of Simple Groups, by Professor E. Hastings Moore, of the University of Chicago.

FRIDAY, AUGUST 25, 3 P. M.

Visit to the German University Exhibit.

SATURDAY, AUGUST 26, 9:30 A. M.

PAPERS—

Der pythagoraische Lehrsatz in mehrdimensionalen Räumen, by Professor V. Schlegel, Hagen, Germany.

La Géométrographie ou l'art des constructions géométriques, by M. Emile Lemoine, Paris, France.

Régle des anologies dans de triangle et transformations continue, by M. Lemoine, Paris, France.

Nomographie: Sur les équations représentables par trois systèmes rectilignes de points isoplèthes, by M. d'Ocagne, Paris, France.

Note concerning Arithmetical Operations involving Large Numbers, by the Rev. T. M. Pervouchine, Kasan, Russia.

LECTURES—

Concerning the Development of the Theory of Groups during the last Twenty Years, by Professor Dr. Felix Klein, of the University of Göttingen, Germany.

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SECTOIN OF ASTRONOMY AND ASTRO-PHYSICS.

In the section of Astronomy and Astro-Physics officers were elected as follows: Chairman, Dr. John M. Thome, Cordoba; Secretary, Professor George E. Hale, Chicago; Committee on Program, Professor P. Tacchini, Rome; Professor J. E. Keeler, Allegheny; Professor G. W. Hough, Chicago; Mr. W. R. Warner, Cleveland, with Chairman and Secretary, *ex officio*.

The following papers were read:

TUESDAY, AUGUST 22.

* On the Physical Constitution of Jupiter, by Professor George W. Hough, Director of the Dearborn Observatory.

* The Two Magnetic Fields surrounding the Sun, by Professor Frank H. Bigelow, U. S. Weather Bureau.

* Electro-Magnetic Theory of the Sun's Corona, by Dr. H. Ebert, Erlangen University, Bavaria.

In the discussion of the last two papers Professor H. A. Rowland expressed his belief in a magnetic condition of the Sun, and remarked that he considered its effect upon terrestrial magnetism a subject well worthy of careful investigation.

* An Absolute Photometric Scale for Spectrum Lines, by Mr. L. E. Jewell, Johns Hopkins University.

In the discussion Professor A. O. Leuschner pointed out that the law of increase in density of a photographic plate strictly proportional to the time of exposure cannot be regarded as correct.

* Variation of Metallic Lines with the Amount of Metal in the Arc, by Messrs. Joseph S. Ames and L. E. Jewell, Johns Hopkins University.

Photographs of Comet *b* 1893. Drawings of Mars. By Professor W. J. Hussey, Leland Stanford University.

The photographs exhibited were a series showing the changes in Comet *b* 1893, taken with a portrait lens at the Lick Observatory. The drawings of Mars were made with the 36-inch telescope during the last opposition.

WEDNESDAY, AUGUST 23.

* On a Practical Method of Determining Double Star Orbits by a Graphical Process, and on the Elements Ω and λ, by Dr. T. J. J. See, University of Chicago.

In the discussion Professor Leuschner said he fully concurred in the main points advanced in the paper, and thought all present would appreciate the great efforts made by Dr. See and Mr. Burnham to bring order out of the chaos hitherto existing in the elements of Double Stars. Yet it seemed to him that if we continually went back to the original measures to check the results of the graphical interpolation, it might in some cases be useful to employ graphical interpolating curves. The method was essentially one of trial and error, the final result to be found by successive approximations.

Mr. Burnham spoke of the practical work of finding double-star orbits, and said his own experience had fully convinced him that the only logical method was to plat the observations directly, and to draw by trial an ellipse which satisfied the distances and at the same time conformed to the law of areas. This was the

* Papers marked with an asterisk will be published in ASTRONOMY AND ASTRO-PHYSICS.

method which he and Dr. See had been using, and those present saw from the diagrams exhibited what results they had obtained.

Mr. Burnham fully approved of the proposed method of taking Ω between 0° and 180°, and of reckoning λ in the direction of the motion. These slight changes in the elements would secure uniformity, and would enable astronomers to at once lay down the apparent orbit of any star from the elements, by using the elegant graphical method discovered by Dr. See and published in the August number of ASTRONOMY AND ASTRO-PHYSICS.

* Great Telescopes of the Future, by Mr. Alvan G. Clark, Cambridgeport, Mass.

In the discussion Dr. J. A. Brashear took exception to Mr. Clark's opinion that the objective-maker must be an artist in color. He held that the spectroscopic examination of the color curve afforded the only certain means of securing correction for a given wave-length. Professor J. E. Keeler suggested the desirability of making the upper end of telescope tubes very large, in order that radiation from the metal may not effect the cone of rays. Professor George E. Hale spoke of the importance of shielding the tube from direct solar radiation, and stated that an electric exhaust fan would be placed at the centre of the tube of the 40-inch Yerkes telescope for the purposeof withdrawing the heated air from time to time in solar work.

Notes on the Construction of the Modern Spectroscope, by Dr. J. A. Brashear, Allegheny, Penn.

A combined Visual and Photographic Objective, by Dr. J. A. Brashear, Allegheny, Penn.

A 12-inch objective made by Dr. Brashear for the Observatory of Beirut, Syria, was exhibited to illustrate this paper. The inner crown glass lens is mounted in a cell, and two flint glass lenses are provided, each in a separate cell of such form that the lens may readily be placed in contact with the crown, and held there without pressure.

On a Perfectly Free Escapement and a Mercury Pendulum, by S. Riefler of Munich, by Professor Leman, Berlin, Germany.

On Double-Star Observations. The Orbit of 85 Pegasi, by Professor S. Glasenapp St. Petersburg, Russia.

* The Bureau of Measurements of the Paris Observatory, by Miss Dorothea Klumpke, Paris Observatory.

At the invitation of Messrs. Warner & Swasey the members of the Congress attended the opening exhibit of the 40-inch Yerkes telescope at the Columbian Exposition on Wednesday afternoon. Professor Felix Klein, Official Delegate of the German Government, conducted the party through the exhibit of the German Universities.

THURSDAY, AUGUST 24.

* The Wave-length of the Two Principal Lines in the Spectrum of the Nebulæ, by Professor J. E. Keeler, Director of the Allegheny Observatory.

In the discussion Professor George E. Hale remarked on the confusion resulting from the use of several standards of wave-length, and moved that a committee be appointed to consider what action, if any, should be taken toward the adoption of an international standard of wave-length. As members of the committee he proposed Professor von Helmholtz of Germany, Professor Mascart of France, Professor Tacchini of Italy, and Professor Keeler of the United States.

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The motion was adopted. On motion of Dr. T. J. J. See a committee consisting of Professor Max Wolf, Professor Benjamin W. Snow, and Professor George E. Hale was named by the Chairman to notify the members of the wave-length committee of their appointment. [Professors Mascart, Tacchini and Keeler expressed their willingness to act, but Professor von Helmholtz's numerous engagements made it impossible for him to accept the appointment. Consideration of the question was therefore deferred.]

* Photographic Investigations of the Sun (illustrated with the stereopticon), by Professor George E. Hale, Director of the Kenwood Observatory, University of Chicago.

In the discussion Professor J. E. Keeler said that a letter had been received from Professor K. D. Naegamvala, Director of the Observatory at Poona, India, stating that if it was deemed desirable he might be able to secure funds for purchasing and operating a spectroheliograph at Poona. Professor Keeler then moved the adoption of the following resolution:

Resolved, that in view of the importance of securing an uninterrupted record of the condition of the Sun's surface by means of photographs similar to those obtained by Professor Hale at the Kenwood Observatory, the Congress of Astronomy and Astro-Physics strongly approves of the proposal of Professor K. D. Naegamvala to establish a spectroheliograph at the Observatory of Poona, India, for the purpose of supplementing the work now in progress at Chicago, and hopes that the proper authorities may see fit to provide the necessary apparatus.

In seconding the motion Professor P. Tacchini dwelt at some length on the importance of such photographs of the faculæ in the study of terrestrial magnetic storms. He advocated the establishment of the spectroheliograph not only in Poona, but also at two other stations respectively 90° east and west of Chicago. The resolution was adopted.

* On the Spectra of the Elements, by Professors Kayser and Runge, Hannover, Germany.

In the discussion of this paper Professor J. E. Keeler remarked upon the value of the method suggested by the authors of identifying lines in stellar spectra by determining the presence or absence of other lines in the same series.

* The Wolf-Rayet Stars (illustrated with the stereopticon), by Professor W. W. Campbell, Lick Observatory.

* Concerning the Nature of Nova Aurigæ's Spectrum, (illustrated with the stereopticon) by Professor W. W. Campbell, Lick Observatory.

* Preliminary Notes on the Corona of April 16, 1893, by Professor J. M. Schaeberle, Lick Observatory.

This paper was illustrated by a complete series of lantern-slides made from negatives obtained by Professor Schaeberle at the recent eclipse.

Photographs of Nebulæ and their Spectra (shown with the stereopticon), by Dr. Eugen von Gothard, Director of the Astro-Physical Observatory, Herèny, Hungary.

Among the spectra shown were those of Nova Aurigæ and a planetary nebula as photographed by Dr. von Gothard with a 10-inch reflector and objective prism. The agreement of the two spectra was very stiking.

Photographs of Minor Planets, Meteors, etc., (shown with the stereopticon), by Professor Max Wolf, Heidelberg, Germany.

Photographs of Stellar Spectra (shown with the stereopticon), by Professor A. O. Leuschner, University of California.

FRIDAY, AUGUST 25.

* Photographic Observations of the Minor Planets, by Professor Max Wolf, Heidelberg, Germany.

* A Field for Woman's Work in Astronomy, by Mrs. M. Fleming, Harvard College Observatory.

In the discussion Dr. J. A. Brashear highly praised the astronomical work of women, and Professor W. H. Pickering testified to the efficient service of the women employed at the Harvard College Observatory.

* Recent Investigations at the Cordoba Observatory, by Dr. John M. Thome, Director.

* The Atmospheric Refraction at Madison, Wisconsin, by Professor George C. Comstock, Director of the Washburn Observatory, University of Wisconsin.

* The Infra-Red Spectrum, by Professor S. P. Langley, Secretary of the Smithsonian Institution, Washington, D. C.

SATURDAY, AUGUST 26.

* Is the Moon a Dead Planet? By Professor W. H. Pickering, Harvard College Observatory.

* The Constitution of the Stars, by Professor Edward C. Pickering, Director of the Harvard College Observatory.

Professor J E. Keeler opened the discussion of this paper, and reviewed the systems of classification of stellar spectra proposed by Secchi, Vogel, Lockyer and others. He expressed his belief that the time has not yet arrived to formulate a complete and wholly satisfactory system of classification.

* Contributions on the subject of Solar Physics, by Dr. Egon von Oppolzer, Vienna, Austria.

* Theory of the Sun, by Dr. A. Brester, Jz., Delft, Holland.

Theory of the Sun, by M. H. Faye, Bureau des Longitudes, Paris.

The Retrograde Rotation of the outer Planets, by Professor W. H. Pickering, Harvard College Observatory.

In accordance with the custom of naming a minor planet at the conclusion of an astronomical congress Professor Max Wolf requested that a name recalling the present congress be given to one of his newly discovered asteroids. He suggested "Chicago" and "Illinoa" as appropriate titles. The former was chosen by vote of the Section.

A vote of thanks to the foreign delegates for their presence and participation in the proceedings of the Section was moved by Dr. J. A. Brashear and carried unanimously.

Professor J. E. Keeler proposed a vote of thanks to the officers of the Section, which was adopted.

The Section then adjourned.

GEORGE E. HALE, Secretary.

XUM

Blueness of the Sky at High Altitudes.

Dear Professor Hale:

When in Chicago last I spoke to you about stopping at several points in Colorado on the return to California to see how the sky looked with the naked eye.

We ascended Pike's Peak August 15th on the Cogwheel railway. The summit was scarcely reached before a heavy snow storm set in, accompanied with thunder and lightning, and sky and plains were blotted out by the enveloping clouds. In descending we found the lower peaks—about 7,000 or 8,000 feet high, covered with snow.

While ascending the mountain we had frequent glimpses of the sky between breaks in the clouds, but never in the direction of the Sun. What we thus saw of the sky seemed fairly blue but not a deep dark blue.

That night we remained at Colorado Springs, 6,000 feet, until eleven o'clock. The sky had cleared and was very dark and rich and the stars shone with great brilliancy. Their light, however, was very unsteady to the naked eye, showing that telescopic observations would have been hopeless. The electric lights everywhere made it impossible to tell just how transparent the sky was, but later, 2 A. M., as we were passing through the Royal Gorge (on the Denver & Rio Grande) the sky as seen from the moving train, gave every indication of great purity.

Marshall Pass (11,000 feet altitude) was one of the points where it had been decided to stop over. As there is no hotel at this point we managed, after some entreaty, to secure the rough accomodations that the section house could afford. We remained at the Pass from 6:30 A. M. of the 16th to the same hour of the 17th.

Close north of the section house stands Mount Ouray, a grand peak a little over 14,000 feet high. Joining this and a little lower and nearer the section house is a smaller peak locally called Little Ouray. This will not be far from 13,500 or 13,900 feet high. This latter peak I ascended as time did not permit the ascent of Ouray proper. I reached the top of the peak at 10:30 A. M. and upwards of three quarters of an hour was spent on the summit above the timber line. The day was very beautiful with magnificent cumulus clouds. The sky was a deep rich blue and perfectly pure. Hiding the Sun with one's hat it was possible to look up close to the solar limb. There was no halo or glare at all about the Sun—the sky being a deep rich blue up to the very limb. While I remained at this point and watched the sky it was forcibly impressed upon me that such a sky would offer the highest advantages in any attempt to photograph the corona without an eclipse. The altitude was somewhat trying but not so much so as at Pike's Peak. A bank of snow gave the means of quenching one's thirst.

Descending to the Pass, the sky, though still very pure, was perceptibly whiter. As the day advanced the clouds finally covered the sky and the night was more or less cloudy. I was up off and on the entire night in hopes of seeing the night sky. At 11 P. M. the clouds broke away for a short time in the north and the sky appeared very fine, but was soon quickly blotted out permanently.

The atmosphere in Colorado during the day was remarkably pure and free from dust—the most distant objects coming out with striking distinctness.

At Grand Junction, 4,600 feet (on the same railroad) we were detained until midnight. The sky was very pure and dark and the Milky Way was a striking object.

In crossing the Sierras it was hoped the sky might prove interesting, but at Summit (over 7,000 feet) at mid-day it was whitish and brightened rapidly in the direction of the Sun. The mountains were filled with dust and haze.

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In connection with this I would say that on July 18, 1892, I spent the night on Wilson's Peak (site of the Harvard College Observatory station) 6,000 feet altitude, near Pasadena in Southern California. I have nowhere seen a finer, clearer sky. The Milky Way was remarkably clear and bright—the star clouds standing out with a distinctness that gave the impression that they were not far away. The atmosphere seemed to be perfectly steady. It perhaps may sound rather strange, but in looking back over the experience of the past few years, I have hardly seen anywhere as clear and rich a sky as sometimes occurred at Nashville, Tennessee, with an altitude of only 600 feet.

From what I have seen and from a conversation with Professor H. S. Pritchett, of St. Louis, Mo., who has had practical observational experience in Arizona, I should think that an observatory placed on some of the high plateau mesas of Colorado or Arizona, where the altitude is all the way up to 5,000 or 6,000 feet, would be a good place for a large telescope, as there might be less chance of atmospheric disturbances than on a mountain peak.

Very sincerely yours,
E. E. BARNARD.

Photography of the Corona without an Eclipse.—The above letter from Dr. Barnard contains much of interest to those engaged in the study of this problem. At Pike's Peak last June the writer observed the sky near the Sun from various points between the base and the summit of the Peak, and noticed a steady decrease of brilliancy with increase of altitude. At times the sky, as seen from the summit, was very dark, but there was invariably a bright halo surrounding the Sun. Swarms of insects above the mountain had a certain share in producing this effect, but the Sun was really never seen under the best conditions, as clouds invariably covered the sky before it reached the meridian. Before the adjustments of the instruments could be completed, fires broke out in the surrounding forests, and the smoke quickly spread itself over the sky, greatly increasing the brightness of the atmospheric glare.

M. Ricco's attempts to photograph the corona at Catania are described in the July number of the *Memorie della Societa degli Spettroscopisti Italiani*. Dr. Huggins' method was employed, and halos resembling the corona in form were obtained in the photographs. A drawing of one of these images accompanies M. Ricco's very interesting paper. Two circumstances lead one to doubt whether the true corona is here represented. In the first place the exposure seems to have been too short to give such marked extension of the streamers. Again four exposures made during the eclipse of April last (which was partial in Catania), show no effect of the Moon in cutting out a portion of the corona. Hence it would seem that the coronal forms obtained must have had their origin between the Moon and the photographic plate. Great care has been taken in the experiments, and it is satisfactory to know that they will be continued. G. E. H.

The Spectrum of Comet *b* 1893. A few observations of the spectrum of comet *b* 1893 were made at Allegheny, too late for insertion in my note in the August number. On July 21 the sky was unusually clear and the spectrum was seen better than on any previous occasion. The second maximum of the green band was easily visible, and the fluted appearance could be traced clear across the coma. The yellow and blue bands also had a fluted appearance, but the maxima were not sufficiently distinct for measurement. The terminal line of the green band was the brightest part of the spectrum. In each of the other two bands, however, the

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greatest brightness was not at the edge, but at a place somewhat above it. A photograph taken a few days later also shows this distribution of light in the blue band.

A number of photographs of the spectrum of a Bunsen burner flame were made with the same apparatus, each with a narrow solar spectrum for reference. One of these, on an isochromatic plate, shows the structure of the carbon bands, from the *D* line to the ultra-violet, with beautiful distinctness, notwithstanding the smallness of the scale.

Comparison of these plates with the comet photograph shows no very striking similarity in the upper part of the spectrum. The blue cometary band agrees in position with the blue band of the Bunsen burner, and lines at λ 388 and λ 387 coincide in both spectra; but in the Bunsen burner spectrum the line at λ 388 is the terminal line of a band facing toward the violet, while its appearance in the comet spectrum is that of a band facing the other way. This appearance may be due to the faintness of the photographic impression on the latter plate. The lines are probably identical.

The great band beginning near G, which is the strongest in the spectrum of the Bunsen burner, does not show on the comet photograph. There is however a slight shade near λ 420, which may possibly represent a group of bright lines photographed by Mr. Campbell. On account of smoke near the horizon all photographic observations were made at Allegheny under a great disadvantage and sometimes a plate was exposed for two hours without any result whatever.

JAMES E. KEELER.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR NOVEMBER.

Mercury will be "evening star" during the greater part of November, coming to greatest eastern elongation, 23° east from the Sun, on the evening of Nov. 5. It will, however, then be at nearly its greatest southern declination, so that it can be seen by northern observers only at a very low altitude. In the southern hemisphere the position of the planet will be favorable for observation during the first half of the month. On Nov. 26, at 6 A. M. Central time, Mercury will be at inferior conjunction with the Sun. The planet will then be 1° 25′ north of the Sun's center.

Venus will also be evening star during November and will be in splendid position for observation from the southern hemisphere of the Earth, but northern observers must content themselves with views at low altitudes. The phase of Venus will be a little more than half full and gradually decreasing, while the apparent diameter of the disk will increase from 18″, Nov. 1, to 24″, Dec. 1. The crescent Moon will pass Venus about noon Nov. 12, so that on that evening and the preceding the two brilliant objects will be near together.

Mars will be morning planet and may be seen in the morning twilight but at so low an altitude that observations will be useless.

Jupiter is the object of objects to be observed by amateur astronomers during November. The planet comes to opposition Nov. 18. It will therefore be visible during the whole night, and as its declination is between 18° and 19° north of the equator, its meridian passage will be at a high altitude. The diameter of

Jupiter's disk during this month will be about 47″, so that not only the belts but many small spots and much fine detail on the planet's surface ought to be visible with telescopes of moderate power. No one can mistake this planet, for his splendid brilliancy outshines any other object in the evening sky, with the exception of the Moon. The latter will pass by Jupiter, about 4° to the north, at about 4 o'clock on the morning of Nov. 23. Jupiter's apparent motion will be westward in the constellation Taurus, a little way south of the Pleiades. For the phenomena of the satellite see the tables which follow these notes.

Saturn has just come out from conjunction with the Sun and cannot yet be seen to advantage.

Uranus will be in conjunction with the Sun at midnight Nov. 2.

Neptune is approaching opposition and is at a high northern declination, so that he may be observed under the most favorable circumstances. The trouble with this planet, for amateurs, is that its disk is so small that it cannot be recognized by that with small telescopes, and its motion is so slow that just now it requires two or three days to make the change of position noticeable. In a photograph taken at Goodsell Observatory on the evening of Sept. 21, with the 2½-inch camera, Neptune is on a direct line between the stars *i* and ε of the constellation Taurus and about one fifth of the distance from the former to the latter star. During October and November the planet will move only 1° 23′ west and 11′ south from its present position. There is but one star as bright as Neptune within a radius of a degree, or twice the Moon's diameter, and that star is toward the north from the planet, so that it is now comparatively easy to identify the planet.

PLANET TABLES FOR NOVEMBER.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

MERCURY.

Date. 1893.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Nov. 5	16 17.2	− 24 10	8 57 A. M.	1 16.3 P. M.	5 36 P. M.
15	16 44.7	− 24 25	8 45 "	1 04.3 "	5 24 "
25	16 15.1	− 20 33	7 18 "	11 55.4 A. M.	4 33 "

VENUS.

Nov. 5	17 53.6	− 26 11	10 33 A. M.	2 52.2 P. M.	7 01 P. M.
15	18 43.8	− 25 59	10 53 "	3 03.1 "	7 13 "
25	19 31.8	− 24 41	10 55 "	3 11.6 "	7 28 "

MARS.

Nov. 5	13 23.7	− 7 59	4 51 A. M.	10 23.2 A. M.	3 55 P. M.
15	13 48.4	− 10 27	4 47 "	10 08.6 "	3 30 "
25	14 13.7	− 12 48	4 42 "	9 54.4 "	3 06 "

JUPITER.

Nov. 5	3 44.0	+ 18 38	5 20 P. M.	12 41.2 A. M.	8 02 A. M.
15	3 38.6	+ 18 20	4 36 "	11 56.4 P. M.	7 17 "
25	3 33.0	+ 18 03	3 53 "	11 11.5 "	6 30 "

SATURN.

Nov. 5	13 14.1	− 5 24	4 32 A. M.	10 13.6 A. M.	3 56 P. M.
15	13 18.3	− 5 48	3 58 "	9 38.5 "	3 19 "
25	13 22.2	− 6 10	3 24 "	9 03.2 "	2 24 "

XUM

URANUS.

	Date.	R. A.	Decl.	Rises.	Transits.	Sets.
		h m	° ′	h m	h m	h m
Nov.	5.....14	35.6	− 14 51	6 32 A. M.	11 34.9 A. M.	4 38 P. M.
	15.....14	38.1	− 15 01	5 56 "	10 58.0 "	4 00 "
	25.....14	40.4	− 15 12	5 19 "	10 21.1 "	3 23 "

NEPTUNE.

Nov.	5.....	4 46.7	+ 20 48	6 12 P. M.	1 43.6 A. M.	9 15 A. M
	15.....	4 45.6	+ 20 46	5 32 "	1 03.2 "	8 34 "
	25.....	4 44.4	+ 20 44	4 52 "	12 22.8 "	7 54 "

THE SUN.

Nov.	5.....14	44.4	− 14 56	6 41 A. M.	11 43.7 A. M.	4 47 P. M.
	15.....15	25.0	− 18 42	6 59 "	11 44.8 "	4 31 "
	25.....16	06.9	− 20 55	7 12 "	11 47.3 "	4 13 "

Minima of Variable Sars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

R. A.....$0^h\ 52^m\ 32^s$
Decl.....+81° 17′
Period.....$2d\ 11^h\ 50^m$

Nov. 3	5 P. M.
6	5 A. M.
8	4 P. M.
11	4 A. M.
16	4 "
21	4 "
26	3 "

ALGOL.

R. A.....$3^h\ 1^m\ 1^s$
Decl.....+ 40° 32′
Period.....$2d\ 20^h\ 49^m$

Nov. 2	9 P. M.
5	6 P. M.
8	3 "
17	5 A. M.
20	2 "
22	11 P. M.
25	8 "
28	5 "

λ TAURI.

R. A.....$3^h\ 54^m\ 35^s$
Decl.....+ 12° 11′
Period.....$3d\ 22^h\ 52^m$

Nov. 3	1 A. M.
6	midn.
10	11 P. M.
14	10 "
18	9 "
22	8 "
26	6 "
30	5 "

R. CANIS MAJORIS.

R. A.....$7^h\ 14^m\ 30^s$
Decl.....− 16° 11′
Period.....$1d\ 3^h\ 16^m$

Nov. 6	1 A. M.
7	4 "
13	midn.
15	3 A. M.
16	6 "
22	2 "
23	5 "

S CANCRI.

R. A.....$8^h\ 37^m\ 39^s$
Decl.....+ 19° 26′
Period.....$9d\ 11^h\ 38^m$

Nov. 12	6 P. M.
22	6 A. M.

S ANTLIÆ.

R. A.....$9^h\ 27^m\ 30^s$
Decl.....− 28° 09′
Period.....$7^h\ 47^m$

Nov. 9	6 A. M.
10	5 "
11	5 "
12	4 "
21	6 "
22	5 "
23	5 "
24	4 "

Occultations Visible at Washington.

Date 1893.	Star's Name.	Magnitude.	IMMERSION Washington M. T.	IMMERSION Angle f'm N pt.	EMERSION Washington M. T.	EMERSION Angle f'm N pt.	Duration.
			h m	°	h m	s	h m
Nov. 14	B.A.C. 7077	6.4	6 22	127	6 56	183	0 34
15	33 Capricorni	5.7	7 05	74	8 19	219	1 14
17	74 Aquarii	6.0	2 14	54	3 23	252	1 09
18	24 Piscium	6.1	11 37	30	12 36	260	0 59
22	r^2 Arietis	5.3	9 01	125	9 30	173	0 29
24	136 Tauri	5.3	17 51	144	18 30	227	0 39
26	ω^1 Cancri	6.0	13 52	138	14 57	249	1 05

Phenomena of Jupiter's Satellites.

		h	m						h	m			
Nov.	2	2	31	A. M.	II	Sh. In.	Nov.		7	12	A. M.	III	Tr. Eg.
		3	23	"	II	Tr. In.			5	29	P. M.	I	Sh. In.
		4	51	"	II	Sh. Eg.			5	35	"	I	Tr. In.
		5	38	"	II	Tr. Eg.			7	42	"	I	Sh. Eg.
	3	5	21	"	I	Ec. Dis.			7	46	"	I	Tr. Eg.
		7	54	"	I	Oc. Re.		15	4	56	"	I	Oc. Re.
		9	33	P. M.	II	Ec. Dis.		17	7	10	"	III	Ec. Dis.
	4	12	32	A. M.	II	Oc. Re.			8	43	"	III	Ec. Re.
		2	38	"	I	Sh. In.		18	2	42	A. M.	II	Oc. Dis.
		3	01	"	I	Tr. In.			4	58	"	II	Oc. Re.
		4	50	"	I	Sh. Eg.			6	27	"	I	Sh. In.
		5	12	"	I	Tr. Eg.			6	27	"	I	Tr. In.
		11	50	P. M.	I	Ec. Dis.		19	3	37	"	I	Oc. Dis.
	5	2	20	A. M.	I	Oc. Re.			5	48	"	I	Oc. Re.
		6	10	P. M.	II	Sh. Eg.			9	01	P. M.	II	Tr. In.
		6	46	"	II	Tr. Eg.			9	04	"	II	Sh. In.
		9	06	"	I	Sh. In.			11	17	"	II	Tr. Eg.
		9	27	"	I	Tr. In.			11	25	"	II	Sh. Eg.
		11	18	"	I	Sh. Eg.		20	12	53	A. M.	I	Tr. In.
		11	38	"	I	Tr. Eg.			12	55	"	I	Sh. In.
	6	6	19	"	I	Ec. Dis.			3	04	"	I	Tr. Eg.
		8	46	"	I	Oc. Re.			3	08	"	I	Sh. Eg.
	7	1	14	A. M.	III	Sh. In.			10	03	P. M.	I	Oc. Dis.
		2	41	"	III	Tr. In.		21	12	17	A. M.	I	Ec. Re.
		3	01	"	III	Sh. Eg.			6	14	P. M.	II	Ec. Re.
		3	56	"	III	Tr. Eg.			7	19	"	I	Tr. In.
		5	47	P. M.	I	Sh. Eg.			7	24	"	I	Sh. In.
		6	04	"	I	Tr. Eg.			9	30	"	I	Tr. Eg.
	9	5	08	A. M.	II	Sh. In.			9	36	"	I	Sh. Eg.
		5	38	"	II	Tr. In.		22	4	28	"	I	Oc. Re.
		7	29	"	II	Sh. Eg.			6	45	"	I	Ec. Re.
		7	54	"	II	Tr. Eg.		24	10	34	"	III	Oc. Dis.
	10	7	16	A. M.	I	Ec. Dis.		25	12	44	A. M.	III	Ec. Re.
		5	22	P. M.	III	Oc. Re.			4	55	"	II	Oc. Dis.
	11	12	08	A. M.	II	Ec. Dis.		26	11	17	P. M.	II	Tr. In.
		2	45	"	II	Oc. Re.			11	42	"	II	Sh. In.
		4	32	"	I	Sh. In.		27	1	33	A. M.	II	Tr. Eg.
		4	44	"	I	Tr. In.			2	03	"	II	Sh. Eg.
		6	45	"	I	Sh. Eg.			2	35	"	I	Tr. In.
		6	55	"	I	Tr. Eg.			2	50	"	I	Sh. In.
	12	1	45	"	I	Ec. Dis.			4	47	"	I	Tr. Eg.
		4	02	"	I	Oc. Re.			5	02	"	I	Sh. Eg.
		6	27	P. M.	II	Sh. In.			11	47	P. M.	I	Oc. Dis.
		6	46	"	II	Tr. In.		28	2	12	A. M.	I	Ec. Re.
		8	47	"	II	Sh. Eg.			6	01	P. M.	II	Oc. Dis.
		9	02	"	II	Tr. Eg.			8	50	"	II	Ec. Re.
		11	01	"	I	Sh. In.			9	02	"	I	Tr. In.
		11	10	"	I	Tr. In.			9	18	"	I	Sh. In.
	13	1	13	A. M.	I	Sh. Eg.			11	13	"	I	Tr. Eg.
		1	21	"	I	Tr. Eg.			11	31	"	I	Sh. Eg.
		8	14	P. M.	I	Ec. Dis.		29	6	13	"	I	Oc. Dis.
		10	30	"	I	Oc. Re.			8	41	"	I	Ec. Re.
	14	5	14	A. M.	III	Sh. In.		30	5	39	"	I	Tr. Eg.
		5	55	"	III	Tr. In.			5	59	"	I	Sh. Eg.
		7	01	"	III	Sh. Eg.							

In. denotes ingress; Eg. egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

XUM

Configuration of Jupiter's Satellites at 10 p. m. Central Time.

Nov.							Nov.							Nov.						
1			4	3	○	2	1	11			1	○	2	3	4	21		4	3	1	○	2	
2	4	2	3	1	○			12			2	○	1	3	4	22			3	4	○	1	2
3		●	4	○	1	3		13		●	2	○	3	4		23	3	2	1	4	○		
4		4	1	○	2	3		14		3	1	○	2	4		24		●	2	○	1	4	
5		4	2	○	3	♌		15			3	○	4	1	2	25			1	○	2	3	4
6		2	4	○	3	1		16	3	4	2	1	○			26				○	2	1	3	4
7		3	1	○	4	2		17		4	2	○	3	1		27			2	1	○	3	4	
8			3	○	2	1	4	18		4	1	○	2	3		28		♌	3	○	2	4	
9	2	3	1	○	4			19		♌	4	○	1	3		29			3	○	1	2	4
10			2	○	3	1	4	20		4	2	○	3	●		30		3	2	1	○	4	

Phases and Aspects of the Moon.

		Central Time.			
		d	h	m	
New Moon	Nov.	8	6	57	A. M.
Apogee	"	11	9	24	P. M.
First Quarter	"	16	11	45	A. M.
Full Moon	"	23	12	08	P. M.
Perigee	"	24	8	00	A. M.
Last Quarter	"	30	3	08	A. M.

Ephemeris of the Fifth Satellite of Jupiter.—We take the following ephemeris by Mr. Marth from the *Monthly Notices* for June, 1893, adapting it to convenient use in the United States. The period of the fifth satellite is assumed to be $11^h\ 57^m\ 21.88^s$, the uncertainty being, according to Mr. Marth, probably within a second of time.

APPROXIMATE TIMES OF GREATEST ELONGATION.

	Greenwich Time.				*Central Time.*			
	East.		West.		West.		East.	
Oct. 5	11	44 P. M.	5	43 A. M.	11	43 P. M.	5	41 A. M.
9	11	22 "	5	21 "	11	21 "	5	20 "
13	11	00 "	4	59 "	10	59 "	4	58 "
17	10	38 "	4	37 "	10	37 "	4	35 "
21	10	15 "	4	14 "	10	14 "	4	13 "
25	9	53 "	3	52 "	9	52 "	3	51 "
29	9	31 "	3	30 "	9	30 "	3	29 "
Nov. 2	9	09 "	3	08 "	9	08 "	3	07 "
6	8	47 "	2	46 "	8	46 "	2	45 "
10	8	24 "	2	23 "	8	23 "	2	22 "
14	8	02 "	2	01 "	8	01 "	2	00 "
18	7	40 "	1	39 "	7	39 "	1	38 "
22	7	18 "	1	17 "	7	17 "	1	16 "
26	6	56 "	12	55 "	6	55 "	12	53 "
30	6	34 "	12	33 "	6	33 "	12	31 "

It will be seen from this ephemeris that the two months of October and November will be very favorable for observations of the satellite, for those who have sufficient optical means. As the times of the satellite's elongations occur at so nearly the same time each night, we have given them only for every fourth night. The others may easily be found by interpolation, the change being five and a third minutes per day. Of course no one will attempt to see this satellite unless he has a telescope of 15 inches or greater aperture.

COMET NOTES.

Discovery of Comet *b* 1893 in June.—Mr. W. E. Sperra of Randolph, O., was so fortunate as to observe the comet, commonly known as Rordame's, nearly three weeks before the discovery was announced. Curiously and unfortunately he mistook it for Finlay's comet, thus losing the credit of an important discovery, and depriving astronomers of a splendid opportunity to photograph the developing tail of the comet as it approached perihelion. The letter following this note gives his own account of the discovery and subsequent observations. Mr. A. G. Sivaslian has extended the ephemeris of the comet back to June 20, using elements III published in August ASTRONOMY AND ASTRO-PHYSICS. The following comparison shows a sufficiently close agreement between the ephemeris and Mr. Sperra's observations to prove the latter genuine.

		Observed				Computed			
	Gr. M. T.	R. A.		Decl.		R. A.		Decl.	
	h m	h	m	°	′	h	m	′	°
June 19	20 25	2	43	+ 17	30	2	41	+ 17	42
21	19 55	2	47	19	35	2	48	19	30
22	20 25	2	50	20	30	2	51	20	30
23	19 55	2	54	21	50	2	55	21	43
25	20 25	3	05	24	30	3	05	24	28
27	20 25	3	21	28	15	3	19	27	29
29	20 25	3	37	31	10	3	37	31	08
July 1	20 25	4	03	36	05	4	04	35	50
3	20 25	4	43	41	20	4	44	41	17
5	20 25	5	36	45	25	5	37	45	25
8	14 55	7	21	49	25	7	20	47	50
9	14 55	8	00	48	50	7	59	47	57
10	14 25	8	31	46	48	8	30	47	00

"I awaited the issue of the August number of ASTRONOMY AND ASTRO-PHYSICS with unusual interest. Permit me to say at once that had the journal appeared in July, or if I had had an ephemeris of Finlay's comet for the month of June, I would have had the honor of announcing the presence of Comet *b* 1893. But as it was I mistook it for comet Finlay, and had no intimation of my mistake, until I received the August number of Word and Works, a meteorological journal published by Ira R. Hicks of St. Louis, Mo. And then, I could scarcely believe that I was mistaken, and that it was a new comet. And so I awaited with unusual interest the August number of ASTRONOMY AND ASTRO-PHYSICS to settle the doubt. When it came, then the fact was revealed to me that I had discovered Comet *b*, 1893, two weeks, four days, and nineteen hours before it was seen by Alfred Rordame on the evening of July 8, 10 P. M.

My discovery of the said comet was on this wise: As above stated, having no ephemeris of Finlay's comet, I approximately extended the search ephemeris of this comet which was printed on page 469 of the May number of ASTRONOMY AND ASTRO-PHYSICS, for June 20, and on the morning of that day I was sweeping for it, a comet was picked up within 3^m of the approximately computed place, and which was supposed to be the comet in question. Its approximate position was found to be 2^h 43^m, R. A., and declination 17° 30′ north, for 3 A. M., local mean time, or 8:25 A. M. Greenwich mean time. It was of about the sixth magnitude or less, round, nebulous with condensation toward centre, perhaps 3′ in diameter. The next morning was cloudy and no observation was made. But the morning of the 22d was a favorable one; its position was then R. A. 2^h 47^m,

and Decl. 19° 35′, although at the time its declination was recorded as 2° less than last given. This also served to make me fail to distinguish it from Finlay's. For the first three mornings I diagramed every star near the comet, and by this means was enabled to detect the mistake in Decl. On the morning of June 24, it was near ε Arietis. I enclose a diagram showing its apparent path among the stars, also a copy of my observations prior to July 10th. The observations are for local mean time; if Greenwich mean time is desired it will be necessary to add $5^h\ 25^m$, to the longitude of Randolph. From the diagram it will be noticed that it passed on June 30 within 2° of ζ Persei, and on July 4 near ζ Aurigæ, and on the 5th near Capella. The comet is shown in Diagram by circle, and which represents its place on morning of dates given at top of diagram. No tail was seen at any of the morning observations. The decrease in size and brightness on several mornings may be due to imperfections of the atmosphere which was foggy most of the time, and moonshine which rendered the sky white. It will be noticed that I have twelve recorded observations of the comet before its discovery on the P. M. of July 8. To make matters worse no newspaper notice of its discovery by Rordame came under my observation, that by this I might have received the hint of its being a new comet, but as it was, I had no hint until as described above. I pointed it out to visitors as comet Finlay, so certain was I that it was that comet. It was seen here at its best on Sunday evening, July 9."

W. E. SPERRA.

Randolph, Ohio, Aug. 7, 1893.

Observations of Comet *b* 1893.

1. June 20, 3 A. M. Picked up while sweeping for comet Finlay, which it was supposed to be. Magnitude 6 or 6½, nebulous with condensation toward center; round, no tail. R. A. $2^h\ 43^m$. Dec. 17° 30′ N.

2. June 22, 2:30 A. M. Seen with naked eye as a faint white spot of light. R. A. $2^h\ 47^m$. Dec. 19° 35′ N.

3. June 23, 3 A. M. R. A. $2^h\ 49\frac{1}{2}^m$. Dec. 20° 30′ N. Description same as above.

4. June 24, 2:30 A. M. R. A. $2^h\ 54^m$. Dec. 21° 50′ N. Diameter 4′ or 5′. 6 Mag.

5. June 26, 3 A. M. R. A. $3^h\ 5^m$. Dec. 24° 30′ N. Description same as above.

6. June 28, 3 A. M. R. A. $3^h\ 21^m$. Dec. 28° 15′ N. Description same as above except smaller in diameter and not so bright, may be owing to poor definition.

7. June 30, 3 A. M. R. A. $3^h\ 37^m$. Dec. 31° 10′ N. Description same as above.

8. July 1, 3 A. M. Position not taken. Magnitude 3½; diameter 6′; fair definition, Moon interference.

9. July 2, 3 A. M. R. A. $4^h\ 3^m$. Dec. 36° 5′ N. Description same as above; sky foggy.

10. July 4, 3 A. M. R. A. $4^h\ 43^m$. Dec. 41° 20′ N. Description same as above; too light and foggy.

11. July 6, 3 A. M. R. A. $5^h\ 36^m$. Dec. 45° 25′ N. Diameter 5′; no distinct nucleus, but dense toward center; 4 magnitude.

12. July 8, 3 A. M. No position taken as out of range of equatorial on account of trees. Near horizon and foggy. Comet appears somewhat dim, but presents same characteristics as in preceding.

13. July 8, 9:30 P. M. R. A. $7^h\ 21^m$. Dec. 49° 25′ N. Near horizon.

14. July 9, 9:30 P. M. R. A. $8^h\ 0^m$. Dec. 48° 50′ N., 3 magnitude; distinct nucleus and train gracefully curved toward Polaris, 15′ in length; coma about 9′ diameter; sky deep clear blue.

15. July 10, 9 P. M. R. A. $8^h\ 31^m$. Dec. 46° 48′ N. Description as above, except tail not so distinct and curved toward β Ursa Minor; the coma has also decreased in diameter, but may be owing to slightly foggy atmosphere.

P. S. My telescope with which the above observations were made is a two-inch objective. Power 36 dia.—

W. E. SPERRA.

Randolph, Ohio.

Passage of Finlay's Comet through the Præsepe Cluster.—In *Astr. Nach.* 3187 Dr. Berberich calls attention to the fact that Finlay's comet will from Oct. 3 to Oct. 8 be passing through the Præsepe cluster of stars, and calculates the following table of times when the comet will be near individual stars of the cluster. We fear however that the comet will be too faint for any one to observe it.

Yarnall's Number	Conjunction in R. A. Paris M. T.		$\Delta\delta$
		h	′
5	Oct. 2	20.9	− 0.2
9	3	3.8	− 2.3
16	3	15.1	− 1.4
37	4	6.0	+ 0.3
59	4	21.1	− 0.6
69	5	2.2	− 1.0
74	5	± 3.0	+ 0.2
89	5	7.5	+ 1.0
134	6	8.8	0.0
148	7	12.7	− 1.4
150	7	17.0	+ 1.9

The Binary Star $O\Sigma$ 82.—Since its discovery this star has described an arc of 87°.4. Although the measures are not numerous, they are pretty exact, and it is now possible to determine the elements of the true orbit. The investigation will be printed in *Astronomische Nachrichten in extenso.* I give here the results obtained:

$$T = 1945.0$$
$$U = 158.4 \text{ years}$$
$$n = -2°.2732$$
$$\Omega = 77°.5$$
$$\lambda = 296°.7$$
$$i = 43\ .8$$
$$e = 0.213$$
$$a = 0''.94$$

Position of the star for 1880:

$$\alpha = 4^h\ 15^m.9 \qquad \delta = +14°\ 46'$$

Magnitudes of the components: 7 − 9.

These elements must be considered as the first approximation; their corrections can be obtained only when new observations will be made. Allow me to call the attention of astronomers possessing large telescopes to this system.

I will be glad to receive any unpublished observations.

By the last measures of Professor S. W. Burnham, we have the following for the relative positions of the components:

1892.00 $\quad \vartheta = 149°.3 \quad \rho = 0''.62$

S. GLASENAPP.

St. Petersburg, Observatory of the University.

XUM

NEWS AND NOTES.

The delay in issuing the first number of *Popular Astronomy* was due to failure in photogravure work on four plates. We have promised good illustration in both magazines and we mean to have it, if it sometimes occasions delay.

The support indicated for *Popular Astronomy* so far is favorable. It seems as if there ought to be sufficient call for such a magazine if we can judge rightly from the indications of the last decade of years. We do not wish to publish a popular magazine of this kind unless it can be well enough supported to enable us to make it first class in every particular, as far as we have ability to do this. The number for October will be an improvement on the previous one, and will probably appear between the 10th and 15th of that month.

Nautical Almanac Office under Investigation.—In our last number we presented a brief report of an investigation of the conduct, by Professor Newcomb, of the Nautical Almanac Office at Washington, D. C. We are advised that Capt. McNair's report on the subject has been submitted to Secretary Herbert, but that his decision has been delayed on account of Professor Newcomb's absence on his summer vacation. Meanwhile its contents appear to be kept strictly secret. We are also advised that we were slightly in error in the statements of our last issue on some points affecting Dr. Morrison; yet, after looking over the various accounts of the trial received, a second time, it is not easy to see wherein we made wrong statements in the matter of fact at issue in our last number. Both Professor Newcomb and Dr. Morrison called for an investigation, grave charges being preferred on the one hand, and serious incompetency alleged on the other. The investigation was ordered promptly and the announcement of the decision only remains. Quite recently we have received considerable information about the specific charges referred to above, both in regard to the management of the Nautical Office and also respecting the ability of the assistants employed. It would be premature to refer to these points specifically pending the announcement of the results of the investigation. What ought to be said later that our readers may understand the merits of the case, as far as we can learn them, we will not fail to give. In our former note we did not mean to question Dr. Morrison's ability as a mathematician, for that would have been out of place at the time; but the manner of presenting his case seemed to us singularly unfortunate, the particulars of which we need not specify. We have held favorable opinions of Dr. Morrison's scholarship mainly because of his reputation and the favorable recommendations from the professors of the Naval Observatory, among others, submitted as evidence in the investigation, a fair example of which is the following testimonial:

"I have the pleasure of certifying that Dr. J. Morrison is the author of one of the best works on Trigonometry I know of in the English language; that he is a teacher of great ability and experience and complete master of all the branches of pure and applied mathematics taught in our best colleges. His ability as a mathematician and astronomer has gained for him not only a high position in this office, but also a wide reputation in this country and in Europe. During my absence for more than a year, he had charge of the mathematical work of this office, and at the same time rendered me valuable assistance in the preparation of my series of mathimatical text books. S. NEWCOMB.

"Nautical Almanac office, May 1, 1886."

A New Escapement for Astronomical Clocks.—At a meeting of the astronomical congress in Chicago, Professor Leman, of the Physical Technical Institute in Berlin, described a new form of clock escapement, which is said to give really wonderful results. Several clocks provided with this escapement are on exhibition in the gallery of the electricity building. The pendulums are also of novel construction, and with the escapement were invented and made by S. Riefler of Munich.

In these clocks, the pendulum is not suspended from a fixed support, but from a brass piece which has a slight rocking motion in the plane of vibration of the pendulum. The axis of rotation is a knife-edge, and it is practically coincident with the axis of the motion of the pendulum. The escapement rocks the support at each swing of the pendulum, so as to bend the spring slightly and give a sufficient impulse to keep up the motion. As the angle through which the support moves is constant, and the friction of unlocking is almost insensible, the pendulum may be considered as almost perfectly free.

The pendulum rod is a Mannesmann steel tube two-thirds of an inch in diameter, about two-thirds full of mercury. The bob is lenticular in shape, and made of bronze. It is not placed at the bottom of the rod, but at some distance from the lower end, the exact position being determined by computation. The coefficient of expansion of each rod is determined separately.

The advantages of this construction are an exact adjustment of the temperature compensation, the quickness with which the pendulum assumes the temperature of its surroundings, and the small effect on the rate of the clock of barometric changes.

The workmanship of the clocks in the exhibit is excellent. A remarkably small driving weight is required in every case.

Trials of one of these clocks at the Munich Observatory, extending over a little more than a year, showed that the rate was extremely uniform. Professor Seeliger regards the escapement and pendulum as constituting a distinct advance in the art of clock-making.

A New Royal Observatory for Edinburgh.—A new and handsome Observatory building is being erected on the Blackfoot Hills just outside of and overlooking the city of Edinburgh. This is to take the place of the old, antiquated and crowded Royal Observatory so long an ornament to Calton Hill.

Dr. Ralph Copeland, Scotland's astronomer Royal, is busily supervising the construction of the new buildings, and will at last have an Observatory worthy of his ability.

The fine instruments given to the Royal Observatory by Lord Crawford, and which were previously at his Observatory at Dun Echt, will be installed in the Observatory as soon as the buildings are completed, which wil perhaps be a year hence.

The new Observatory, besides containing one of the finest astronomical libraries, and various offices, will have at its ends two large cylindrical domes. In the largest of these will be placed the fine 15-inch refractor of Dun Echt. The smaller dome is to be occupied by the 24-inch reflector of the old Observatory, which Dr. Copeland hopes here to put to good use in measuring the lunar heat. The fine meridian circle of Dun Echt will be handsomely mounted in a detached building.

There are also to be handsome and comfortable residences for the Astronomer Royal and his assistants.

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In the erection of this new building, the government has had an eye to beauty as well as to utility, and when finished it will be architecturally one of the handsomest observatories in existence. It is in the midst of a public park and cannot be crowded out by residences. It will be in full view of the city of Edinburgh and will doubtless be pointed to with pride by the inhabitants of that beautiful city. It is only a couple of miles distant, across the city, from the old Observatory.

The new Observatory is now about half finished and is built of a light-colored sandstone which is very durable.

Dr. Copeland, with an eye to a possible large refractor in the future, has made the domes amply large enough to accomodate a telescope comparable with the best now in use.

The present position of the Royal Observatory in the midst of Edinburgh's dust and smoke, has been a great drawback to delicate work. Dr. Copeland, however, says that there was never any trouble from vibrations from the city around and below, from which he thinks the rock composing Calton hill is not continuous.

Engraving in Knowledge.—The August number of *Knowledge* (London, 326 High Holborn, W. C.) contains a number of admirable photo-reproductions of some splendid Moon negatives made by the Henry Brothers of the Paris Observatory.

These pictures which are very sharp and clear were enlarged direct in the principal focus of the telescope. The magnifying power was fifteen times. These pictures illustrate a very interesting paper on the surface features of the Moon by Mr. A. C. Ranyard, the editor. This number of *Knowledge* also contains an excellent paper by Miss Agnes M. Clerke on the Sun as a bright line star.

Mr. Ranyard deserves great credit for the most excellent manner in which he presents to the public in *Knowledge, regardless of expense*, such admirable reproductions of the latest photographs of the celestial bodies. Many of these pictures would otherwise not be seen even by the average astronomer.

On a Wind Screen for Large Refractors.—In connection with the remarks that have lately appeared in ASTRONOMY AND ASTRO-PHYSICS about the necessity of a protecting screen in the observing slit of the 36-inch dome at the Lick Observatory, the following may not come amiss.

The importance of such a screen has been recognized at Nice and at Meudon. These observatories possess two of the largest refractors in Europe. The telescope at Nice has been in operation some years, while the great telescope at Meudon is just being erected under the supervision of M. Janssen.

At Nice it was found necessary to introduce some form of screen in the slit to shield the telescope from the wind. A system of canvas screens hinged to the inside of the slit and opening outwards by cords hanging down inside the dome, was found to work most effectually, and permitted the use of the telescope at times when it would otherwise have been impossible to use it on account of the wind.

At Meudon protection from the wind will be effected by a different form of screen, which has just been put in by M. Gauthier, who is mounting the great telescope. This is a canvas curtain working from the bottom of the observing slit on endless chains running up inside the dome on each side of the slit. It is easily and conveniently raised to any position by a rope. This is exactly the

form of screen suggested by me as a wind guard for the slit of the 36-inch dome on Mt. Hamilton.

At Meudon it is a perfect success and will permit the use of the great telescopes at all times when the sky is clear. The device is simple and inexpensive and is indispensible in the use of large refractors.

It is altogether probable that such a screen will improve the definition, as it will prevent a disturbance of the atmosphere in the dome by wind currents.

Professor George Davidson has suggested (ASTRONOMY AND ASTRO-PHYSICS, 379) the substitution of a netting instead of canvas in making the screen. His great experience in observing in exposed and windy positions should give his suggestion great weight. I am myself not able to say just what effect a netting would have in stopping or rather in breaking the force of the wind. If it is effective, it is much to be prefered to canvas for the reasons suggested by Professor Davidson. E. E. BARNARD.

Alantic Ocean, Aug. 1, 1893.

A New Astronomical Observatory at Manila.—An important astronomical Observatory is soon to be established at Manila. Among other instruments it will contain a photographic meridian instrument of unique design, and a large refractor by Mertz.

Manila is in the Phillipine Islands in latitude about 14° north, and differing some 180° in longitude from Washington.

The large telescope is to be the same size as those at Milan (Professor Schiaparelli's) and Strasburgh.

The object glass of this instrument, which is 19.2 English inches in diameter, is already finished by Mertz. The mounting is being made by Saegmuller, at Washington, and will be similar to that of the 12-inch at Washington, which was designed by Professor Harkness.

This telescope will also be provided with a photographic correcting lens—perhaps by Mertz.

Besides regular visual work, it is intended to use the instrument for photographic observations of the double stars, spectrographic work, photographic parallax, etc.

Father Algue, of the Georgetown Observatory, is at present in Europe and will bring back with him the large objective, and when the instrument is finally finished, he will proceed with it to Manila, where he will place it in position and begin work with it.

At present there is no astronomical Observatory at Manila. There is, however, a government meterological and seismographic Observatory at that point.

Besides the establishment of this Observatory at Manila, Father Algue will also undertake there a series of latitude observations in connection with a similar series to be carried on by Fathers Hagen and Fargis at the Georgetown Observatory for the determination of the variation of latitude.

These observations (at both stations) will be made by the aid of photography. They will extend over several years, begin about the last of 1893 or the first part of 1894. Talcott's Method by pairs of stars in the meridian, will be employed. Though at both stations star trails will be used for the work the instruments will differ considerably in principle.

They will both float in Mercury and will have a free motion north and south only.

At Georgetown, the instrument with a sensitive plate in its focus, will be di-

rected to the first star of the pair, and as the star crosses the meridian it will leave a trail on the plate. The instrument is then reversed and the other star allowed to trail on the same plate. The observation will consist in a combination of the circle readings and the measurement of the distance between the two trails.

As the stars cross the meridian the trails are broken by aid of the photochronograph indicating the points from which measurement must be made.

The corresponding instrument at Manila will consist essentially of two telescopes in the same tube—or at least there will be two object glasses one at each end of the tube, their foci coinciding. These will be of the same diameter and focus—the tube being equal to the sum of the focal lengths of the object glasses.

At the common focus of these lenses—in the middle of the tube— is placed a sensitive plate.

The telescope remains stationary throughout the observation of both stars. By the aid of the upper objective the first star trails on the upper side of the sensitive film. A basin of mercury now reflects the image of the second star up through the second object glass (in the lower end of the tube) where it trails on the underside of the same film—*through the plate.*

The objectives for these instruments are 6 inches in diameter and 3 feet focal length.

A Great Refractor for Dr. Janssen at Meudon.—A great refractor is just finished and placed in position for Dr. Janssen at Meudon.

It is a combined photographic and visual telescope. The two lenses were made by the celebrated Henry Brothers of the Paris Observatory.

The mounting is by Gauthier of Paris.

Both lenses will be mounted in the same tube which is *square* and of steel.

The visual objective is 82 c. m. (32 3 English inches) in diameter, while the photographic objective is 63 c. m. (24.8 English inches) diameter. Both lenses are of the same focal length, 17 meters (669 English inches).

The large objective will be the guiding part of the instrument when used for photography.

This great telescope is housed in the ruins of the old Royal Palace—a part of the ruins serving as the tower for the great dome, which dome is 20 meters (66 English feet) in diameter and weighs some 60 or 80 tons. The dome is to be moved by a gas engine of 12 horse power. The observing chair is attached to the dome and moves with it. All the fine circles are to be read from the eye end by means of electric lights, the electricity for which is generated by an 8 horse power engine half a mile distant in what was formerly the Royal Stables.

Professor Schaeberle's Theory of the Corona.—At the last meeting of the British Astronomical Association the late solar eclipse was the subject of some discussion by Professor Pickering, Mr. Taylor and others, who had taken part in the observations. We extract the following, with reference to Professor Schaeberle's theory of the corona, from the report of the meeting given in the English Mechanic of July 14.

"Capt. Noble, reverting to the matter of the eclipse, remarked that most of the members should be aware that Professor Schaeberle of the Lick Observatory, had a mechanical theory of the corona, and had made a sketch of what, according to his theory, the appearance of the corona would be at the time of the eclipse. He could not trace the slightest resemblance between this and the photograhps he had seen, and would like to ask Professor Pickering, Mr. Fowler and Mr. Taylor if their observations tended to confirm this.

Professor Pickering said that, as far as his observations went, they did not seem to agree at all with Professor Schaeberle's predictions.

Mr. Taylor had thoroughly examined his photographs, and could not trace the slightest resemblance. The most remarkable thing in them was the great extension at the pole. Mr. Wesley could trace this for two diameters. Professor Schaeberle showed on his drawing some short ones at the pole and a little at the equator.

Mr. Fowler said that he also had been unable to see any resemblance."

In Professor Schaeberle's note on page 693 will be found his answer to these and other similar criticisms.

Correction to the Article: On the Formation of Rings as a Process of Disintegration.—In my remarks about the formation of rings on page* 333, etc., of this year there is a lack of clearness if not quite an important error. The simple excess of attractive power of the main body over that of the satellite would not be evidently sufficient to carry away a free body from the latter as might have been easily inferred from my statements. The fact that the satellite describes a closed orbit about the main body proves, of itself, that the attraction of gravitation, as in the planetary system everywhere, exactly counterbalances the attractive power, because the whole satellite and each body upon it falls for the necessary amount towards the principal body. In regard to this read again what I wrote on page 335: "A free moving object on the surface of the new moon must instantly fly away from it towards Jupiter as soon as the latter rises above the horizon." By this, was expressed, although in a deplorably obscure way, the effect due to the difference of the attraction which the main body exerts upon the remotest and nearest points of the satellite, as a kind of tidal attraction. I have never thought an actual falling, or approaching of the loosened parts as occurring, for I later always, speak only of a ring at the distance of the satellite. The above mentioned reference further shows that I have assumed a rotation of the satellite around its axis which differs from the time of its revolution, because only in this way can the primary body rise and set for the satellite. This improbable assumption for so near a body further complicates the question, and doubtless I am to be blamed because I did not more thoroughly prove it mathematically. In the meantime this has been done in a thankworthy manner by Professors Schiaparelli and Seeliger and by our Dr. Schwahn. These researches in close agreement with one another, led to the result that a satellite whose diameter compared to that of the main body is small, and whose density is equal to it can not exist as such when its distance from the principal body is less than 2.1 semi-diameters of the latter. Now, since the new moon is distant from Jupiter 2.7 of his semi-diameters, the critical distance is not yet reached; consequently the moon cannot be disintegrated by the force of gravitation, although it is very near the limit of possible stability. On the contrary the rings of Saturn lie within the mentioned zone, and therefore the conclusions reached in this case in my article remain untouched. But as regards the dissolution of the moons, in the place in question, we would be obliged to depend on the small initial forces which might have been called forth at the time of separation by uneuqal temperature, expansive or explosive powers, or by disturbances of the other moons of Jupiter. In fact, if an exceedingly small force moves a free body on the surface of such a near moon in a tangential direc-

* *Urania* probably. See ASTRONOMY AND ASTRO-PHYSICS, May, 1893, page 407. —Editor.

tion in its plane of motion, it follows since the particle has only a very small gravity toward the satellite, that thus its motion away from the adjacent body must, under certain circumstances, go on continually, and that means that such particles must form a ring aronnd the main planet. This process, moreover, may begin long before the satellite has reached the above mentioned critical distance.

We now recapitulate: A free body, on the satellite named in my first article, has, as there mentioned, under the suppositions made, no gravity towards the latter, but does not leave it, without some further causes, as there assumed. It must, moreover, at least, as long as its distance from the main planet is greater than 2.1 semi-diameters of the latter, possess an initial velocity which will drive it away from the surface. On the contrary, as just mentioned, if the distance is less, destruction will speedily follow through the attractive force of the main body. The new moon of Jupiter is only a small distance outside of the limit named.

If I had known earlier that this question might take such a complicated form, and what would have been my duty in respect to it, I would not have dared to publish the article in our journal, since it is not our custom to bring out hypothetical things until they have passed the judgment of the professional circle. Now, unfortunately nothing else is possible but to refer to it again.

M. WILHELM MEYER.

A Field for Woman's Work in Astronomy.—This is the title to a valuable paper beginning on page 683 of this number. It is due to Mrs. M. Fleming, the writer, to say that it was prepared for the "Woman's Branch" and was therefore addressed to women and not to astronomers. If she had supposed that it would be read in the Astronomical Congress the language of some parts of it, she says, would have been changed. On account of Mrs. Fleming's wish this reference to the article is made, although we had in no way regarded the apt and direct language of it, as at all inappropriate for the welcome place accorded the paper in the Astronomical Congress at Chicago.

Astronomical and Physical Society of Toronto.—We are sorry to say that after vacation months we are taxed to give all the interesting matter in hand space. The reports of late meetings of the Astronomical and Physical Society of Toronto are full of useful and interesting matter and deserve place in this number, but we have had to pass them with several excellent articles that are waiting our next issue.

On a Recent Theory of Ring Formation.—In the May number of this Journal, there appeared an article on "The Formation of Rings as a Process of Disintegration," by Dr. M. Wilhelm Meyer. In the article referred to, the author endeavors to show that in the case of the fifth satellite of Jupiter, there is a tendency of all loose fragments of matter to fly off towards its great primary, whenever the latter has risen above the horizon to such fragments, by reason of the preponderance of the attractive force of Jupiter over that of the satellite, as measured at the surface of the latter. He further states that both of the satellites of Mars, the first satellite of Jupiter, the first three satellites of Saturn and the first two satellites of Uranus are in the same situation in this respect. In this brief article I merely wish to call attention to the fact that the author, in discussing the question as to the effect of the planet's attraction on loose objects situated on the surface of the satellite, has neglected to take into account the

effect of centrifugal force, due to the satellite's orbital motion. If we denote the planet's attractive force, as exerted at the surface of the satellite, by G the centrifugal force resulting from the satellite's orbital motion by F, and the attractive force due to the mass of the satellite by g, then there will be a tendency for loose fragments to fly off, or to leave the surface of the satellite, only when $g < G - F$. It is hardly necessary to state that such a condition does not exist in the case of any of the known satellites of the solar system. If we suppose the diameter of the fifth satellite of Jupiter to be 100 miles, and its density to be equal to the surface density of the Earth, or say one-half of the Earth's mean density, as it is likely to be, approximately, and its distance from Jupiter's center to be 112000 miles, then for a particle situated on the surface of the satellite, with Jupiter in its zenith, we shall have $g = 17\,(G - F)$, if we suppose the satellite to be without rotative motion. $G - F$ represents, in this case, simply the difference between the attractive force of Jupiter as exerted at that point on the surface of the satellite which is nearest to him, and that exerted by the planet at the center of the satellite. In order that there should be a tendency, in the case of this satellite, for detached fragments of matter to fly off, its density would have to be less than the one-seventeenth part of the Earth's surface density, or less than 0.16 the density of water.

This oversight of the author, here pointed out, was noticed on my first reading the article referred to in the May number of this journal, but thinking that some one else, or perhaps the author himself, would notice and call attention to it, I deferred doing so myself till now. It is almost needless to state that when the proper corrections are made in Dr. Meyer's computations, it will be seen that there will be no tendency to the formation of rings in the manner he indicated.

ROBERT HOOKE.

Jupiter's Comet Family.—In the first number of *Popular Astronomy* some errors seemed unavoidable. The errors of names in the plate could not be corrected because engravers were much behind time. Several members of the family also were not given. Another plate will be given soon which will correct these obvious errors. A list of the elements of orbits of these comets will accompany the new plate.

BOOK NOTICE.

The Planet Venus. A short summary of the present knowledge of the planet, by Ellen M. Clerke. Publishers *Knowledge*, office London, pp. 60.

This little monograph is a worthy companion to its predecessor of last year, Jupiter and His System, and is intended to fill a similar place. There is an introductory chapter of much interest on Venus as the Hesperus and Phosphor of the Greeks, while the last chapter discusses her claims to being the star of Bethlehem. The intermediate pages are filled with a lucid description of the various phenomena to be observed, and a careful discussion of the vexed questions of the planet's period of rotation and the existence of a satellite.

Were the author unknown we should never suspect that the severely plain style in which Jupiter is described and the graceful imagery with which the story of Venus has been clothed could have a common origin. For they are as different as the cold majesty of the one with his court of satellites, and the simple beauty of the other. There will always be a place for such publications which, while laying no claim to exalted merit, still, from the heterogeneous mass of observations good, bad and indifferent, select the salient points and arrange them in logical and readable form. Its publication is especially well-timed, since Venus as evening star will receive much attention in the next three months from astronomers professional and amateur.

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PUBLISHER'S NOTICES.

The subscription price to ASTRONOMY AND ASTRO-PHYSICS in the United States and Canada is $4.00 per year in advance. For foreign countries it is £1 or 20.50 marks per year, in advance. Recent increase in price to foreign subscribers is due to increase of postage because of enlarged size during the year 1892. Messrs. Wesley & Son, 28 Essex Street, Strand, London, are authorized to receive subscriptions. Payment should be made in postal notes or orders or bank drafts. *Personal checks for subscribers in the United States can not longer be received.*

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All communications pertaining to Astro-Physics or kindred branches of physics should be sent to George E. Hale, Kenwood Observatory, of the University of Chicago, Chicago, Ill.

For information of correspondents, the names and addresses of the associate editors of ASTRO-PHYSICS are given as follows:—

James E. Keeler, Observatory, Allegheny, Pa.; Henry Crew, Northwestern University, Evanston, Ill.; Jos. S. Ames, Johns Hopkins University, Baltimore, Md.

All matter or correspondence relating to General Astronomy, remittances, subscriptions and advertising should be sent to Wm. W. Payne, Publisher and Proprietor of ASTRONOMY AND ASTRO-PHYSICS, Goodsell Observatory of Carleton College, Northfield, Minn.; and the Associate Editors for General Astronomy are: S. W. Burnham, Government Building, Chicago Ill.; E. E. Barnard, Lick Observatory, Mt. Hamilton, Cal., and H. C. Wilson, Goodsell Observatory, Northfield, Minn.

Manuscript for publication should be written on one side of the paper only and *special care should be taken to write proper names and all foreign names plainly*. All drawings for publication should be *smoothly* and *carefully* made, in *India Ink* with lettering well done, because such figures are copied exactly by the process of engraving now used. If drawings are made about double the size intended for the printed page, better effect will be secured in engraving than if the copy is less in size. It is requested that manuscript in French or German be typewritten. If requested by the authors when articles are sent for publication, *twenty-five* reprint copies, in covers, will be furnished free of charge. A greater number of reprints of articles can be had if desired, at reasonable rates.

Rates for advertising and rates to news agents can be had on application to the publisher of this magazine.

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